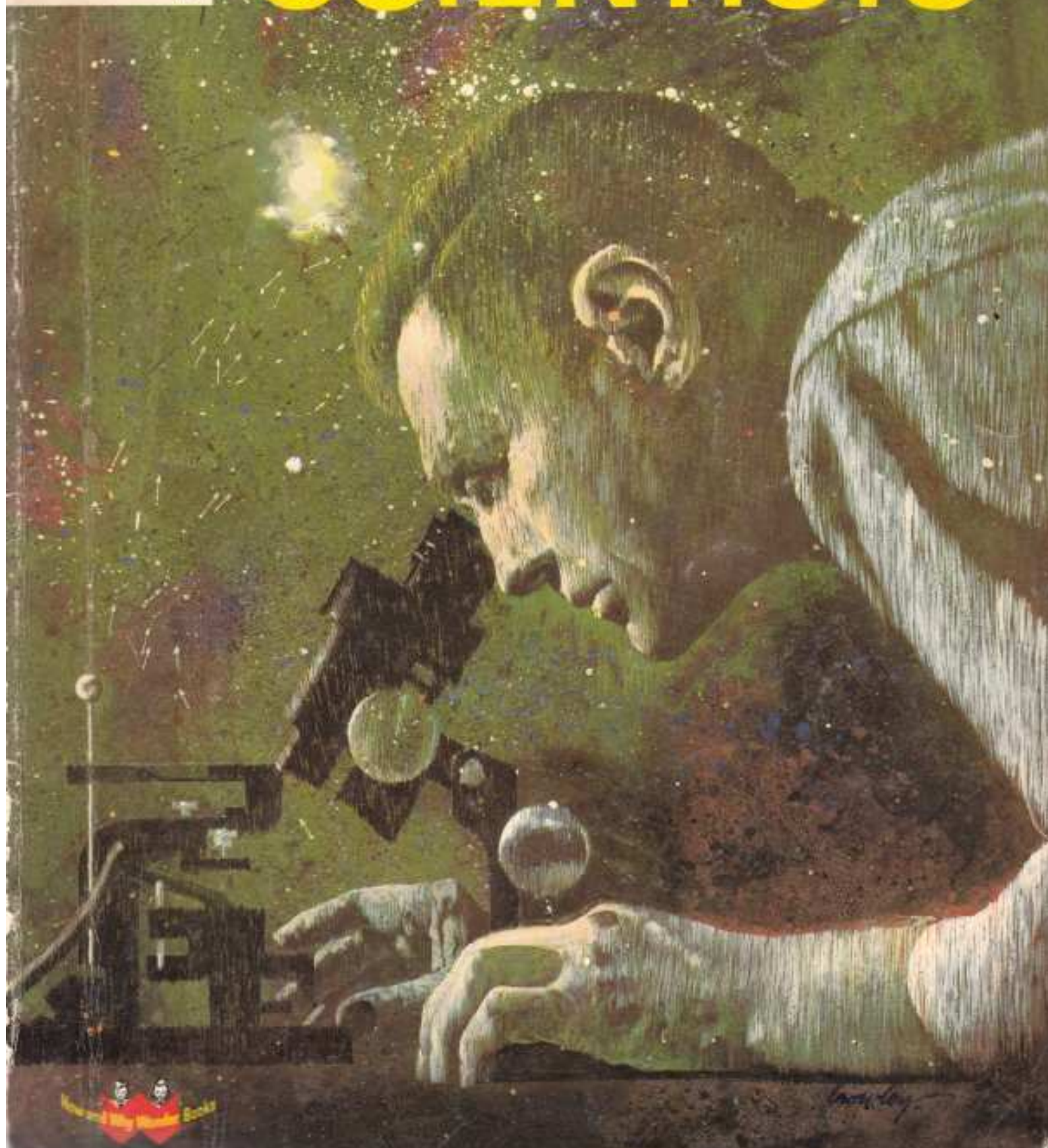


The
**HOW
AND
WHY**
Wonder Book of

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FAMOUS SCIENTISTS





THE HOW AND WHY WONDER BOOK OF

FAMOUS SCIENTISTS

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Introduction

In an age when science touches the lives of everyone, it is surprising to discover that many persons do not understand what science is. To remedy this, it has been suggested that we say *science is what scientists do*. This is an intriguing idea. What do scientists do? To get the answer, we must examine the lives and work of scientists. This is exactly what the *How and Why Wonder Book of Famous Scientists* does.

From a study of the lives of scientists, we learn that science is many interrelated things. We see that scientists are often doubters of traditional answers. They are curious investigators. They do not easily give up their search for answers to difficult questions.

Above all scientists use their heads. They think. They collect evidence and analyze it. They check it carefully in many ways. Sometimes in the process of thinking long and hard about a problem, scientists have important insights — mental leaps — toward the solutions. They test these insights and encourage other scientists to test them.

They make predictions. If their predictions do not work out, they try other reasonable predictions. They are open-minded and willing to change their ideas when new and accurate information is discovered. Always they attempt to make more and more accurate descriptions and explanations of events in our universe. Thus, scientific knowledge grows.

Evidences of all these characteristics of scientists at work are found in this *How and Why Wonder Book of Famous Scientists*. Reading this book at home or at school will help pupils know what science is by learning what scientists do.

Paul E. Blackwood

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Contents

WHAT IS A SCIENTIST?	3
ARCHIMEDES	4
Why is he considered one of the early "true scientists"?	4
NICOLAUS COPERNICUS	8
What did he find out about the solar system?	8
GALILEO GALILEI	11
How did he show the world that a scientist cannot be bound by superstition?	11
WILLIAM HARVEY	14
Why is his work considered a major scientific breakthrough in medicine?	14
ANTON VAN LEEUWENHOEK	17
How did the owner of a draper's shop become a member of the Royal Society?	17
ISAAC NEWTON	21
Why was he once called the "greatest genius of all time"?	21
MICHAEL FARADAY	23
What made him the Pioneer of the Electrical Age?	23
CHARLES LYELL	26
How did he become the Father of Geology?	26
CHARLES DARWIN	28
What is the "survival of the fittest"?	28
LOUIS PASTEUR	32
How did the son of a soldier in Napoleon's army become one of France's most celebrated scientists?	32
GREGOR JOHANN MENDEL	35
How did he lay the foundation for the study of heredity?	35
MARIE CURIE	38
How did her tireless work earn her two Nobel prizes and the first professorship for a woman?	38
ALBERT EINSTEIN	42
How did his formula of 1905 lead to the atom bomb of 1945?	42
ALEXANDER FLEMING	45
Why did he consider his discovery a stroke of good fortune?	45



What is a Scientist?

At Cape Canaveral, Florida, two men in a control tower watch anxiously as a huge missile rises into the air.

In South America, a young lady kneels in a dark cave, carefully brushing dirt from a gleaming human skull.

In a New York laboratory, a man in a white coat skilfully extracts venom from the fangs of a poisonous snake.

These people could be characters in an exciting adventure story. Actually, they're real people. Each one is a scientist, working hard at his own special job. Each one is looking for facts that will solve a particular problem.

Science is a careful, systematic search for facts. Scientists are investigators. They ask questions about the universe and the natural laws that govern it. By observing and experimenting they try to find out the answers to those questions.

Great scientific discoveries seldom happen by accident. They are nearly always the result of keen observation, accurate experiments and a great deal of hard work. Although all scientists

have their own individual ways of working, they usually follow a general pattern known as the *scientific method*.

It starts with *observation*. The scientist is a trained observer. After studying all the *known* facts about the problem he's working on, he gathers additional facts through his own personal observations. From them he develops an idea or *hypothesis* that he hopes will explain or solve the problem.

Next, he *experiments*. He makes careful tests to find out just how true his hypothesis is. Very often, he discovers that it is wrong. But sometimes he is able to collect enough evidence to prove that his idea is right.

After his hypothesis has been thoroughly tested by many other scientists and found to be absolutely correct, it becomes known as a *law* or *principle*. All this may take months, years, or even a whole lifetime. But when it does happen, that scientist has the satisfaction of knowing that he has added an important bit of knowledge to the world's storehouse of information.

A scientist has a choice of many subjects to investigate. He may be interested in the earth itself — its structure and its history. An earth-investigator is called a *geologist*.

Biology is the study of all living things that inhabit the earth. A scientist who studies animals is a *zoologist*. One who investigates plants is called a *botanist*.

The investigation of how plants and animals function is called *physiology*. *Medical research* and *bacteriology* are sub-divisions of this science.

A scientist who studies the sun, moon, stars and planets is an *astronomer*.

Chemistry is the study of the materials that make up the universe, and the various changes that take place in those materials.

Physics is the investigation of matter and energy, such as heat, light, sound and electricity.

Mathematics is the science of numbers. It is used in nearly all the other sciences for measuring and counting and for solving all kinds of problems.

Of course, each main branch of science is divided into many smaller, specialized sections. One man may concentrate mainly on discovering the age of the earth. He is called a *geochemist*. Another may work exclusively in the field of man-made spacecraft. This science is known as *celestial mechanics*. A scientist who specializes in the study of disease-causing agents called viruses, is known as a *virologist*. There are already dozens of scientific specialties, and new ones are rapidly appearing.

In every field of science there are certain men and women whose work has been outstanding. Here you will read about just a few of the world's most famous scientists. Of course, there are many others, equally interesting and important.

Perhaps this book will make you curious to find out more about scientists, how they work and what kind of people they are. Perhaps you, too, will come to share the one thing all scientists, everywhere, have in common: an intense desire to discover new truths about the world they live in.



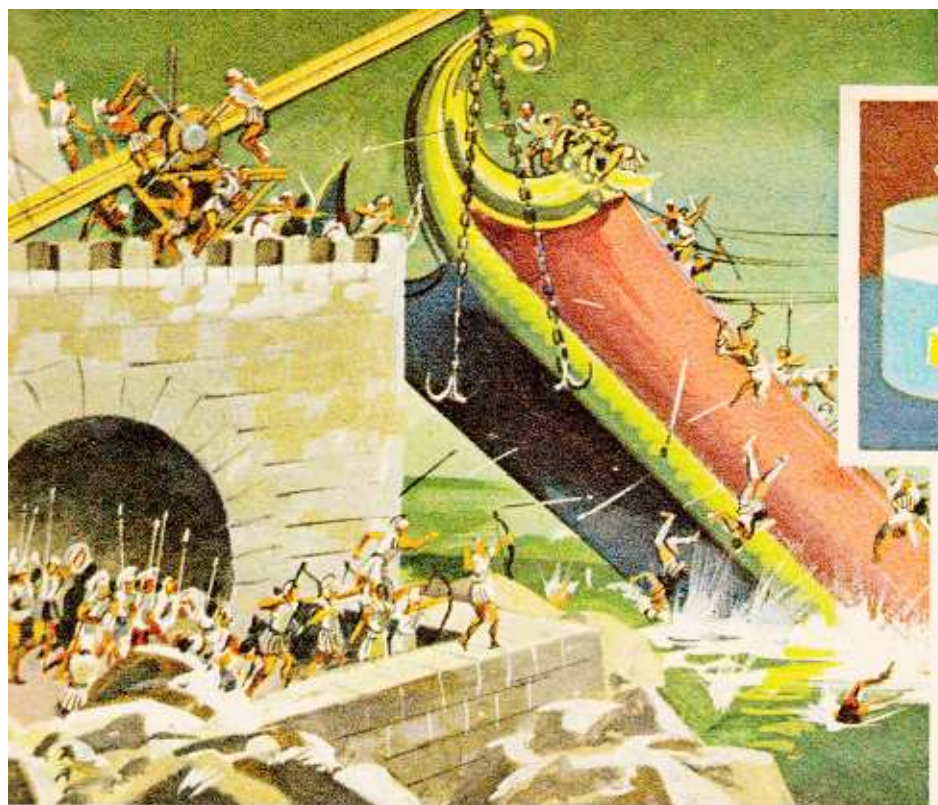
Archimedes

(287-212 B.C.)

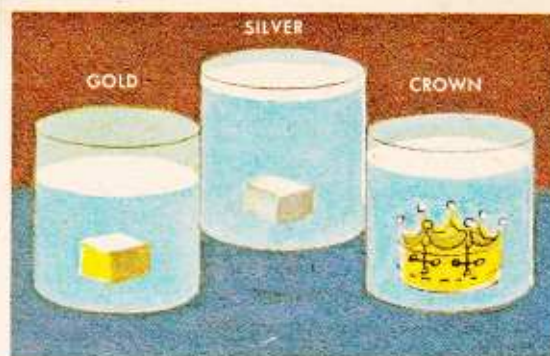
Why is he considered
one of the early
"true scientists"?

Have you heard about one of the most important baths in history? According to a famous legend, it happened

over two thousand years ago in the ancient Greek city of Syracuse. A famous Greek scientist named Archimedes (Ar-ka-mead-eze) stepped into a tub full of water at the public bath house. As he settled back and watched the water flow out over the sides of the

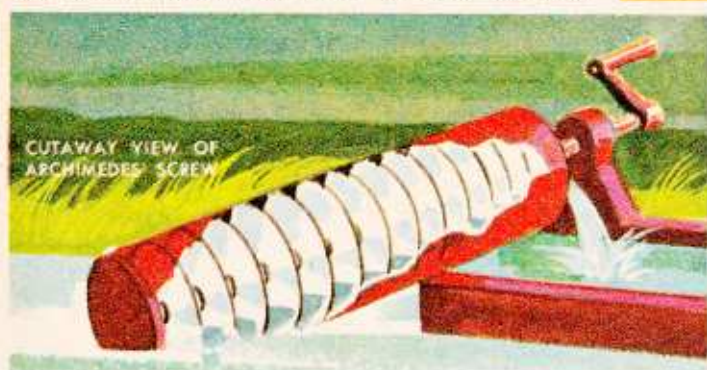


According to legend, a clever construction of pulleys invented by Archimedes pulled Roman war ships out of the water during the siege of Syracuse.



How Archimedes solved King Hiero's problem and discovered what is called today the Law of Specific Gravity.

The principle of the water-screw, invented by Archimedes, is still used.



tub, he was suddenly struck by a wonderful idea. He leaped out of the tub, wrapped a towel around himself and went running toward home.


"Eureka! Eureka!" he cried. "I've found it! I've found it!"

What Archimedes found when he stepped into that bathtub was the answer to a problem he had been working on for some time. The Greek King Hiero had ordered his royal jeweller to make a new crown, and had given him a certain amount of gold to make it with. But the King suspected the jeweller of

stealing part of the gold, and replacing it with cheaper silver. Hiero asked his court scientist, Archimedes, to find out the truth of the matter.

Archimedes knew that metals have different weights. A cube of gold is heavier than a silver cube the same size. He *could* melt the crown and mould it into a cube, then compare its weight with the weight of a cube of gold the same size. But that would ruin the crown. There must be some other way to do it.

He was considering this perplexing



problem that day at the bath house, so the story goes. He noticed that the water level in the tub rose when he immersed his body; or, the weight of his body displaced a certain amount of water in the bathtub. He rushed home and began to experiment with weights and containers of water. He soon discovered that different materials do not displace the same amount of water. Since gold is heavier than silver, a cube made of a pound of solid gold is smaller than a cube made of a pound of solid silver. Archimedes discovered that the gold cube displaces less water than the silver.

Archimedes used this principle to find out if there was any silver in the crown. In one container of water he put an amount of gold equaling the weight of the crown. In another container he put an amount of silver equalling the weight of the crown. In a third one he put the crown itself. He found that the crown displaced more water than the block of gold and less water than the block of silver. This told him that the crown was not solid silver or solid gold, but a mixture of both. The King's jeweller lost not only his job but his life after his dishonesty was uncovered by Archimedes' experiment.

He had solved the King's problem. But that wasn't all. He had discovered one of the most important secrets of nature — solids can be measured by the amount of water they displace. This law is now called Archimedes' Principle, or the Law of Specific Gravity. Today, over twenty centuries later, scientists still depend on this law for many of their calculations. Our modern sub-

marines are built and operated according to this principle.

Archimedes was one of the few early scientists to conduct actual experiments to prove his theories. Many philosophers and mathematicians of those early days were content to think up theories without bothering to prove that they were correct. But Archimedes wanted evidence that his ideas were really workable.

His experiments resulted in some remarkable inventions. One great invention whose basic principle is still used today was the Archimedean Screw. This was a kind of giant corkscrew enclosed within a hollow cylinder. When the end of the cylinder was placed in water and the screw was turned, it scooped up the water and raised it to a higher level. Improved versions of this machine are used today to drain swamps, to convey grain into huge storage bins, and to lift coal into industrial furnaces.

There are stories about some other



machines Archimedes is supposed to have invented. Although historians now doubt that they are true, they are still interesting to read. For instance, it is said that he built a machine that could move huge weights with very little effort. To demonstrate this machine, he attached one end of a chain to a ship loaded with cargo. He ran the chain through the pulleys of the machine and handed the end of the chain to King Hiero. The King tugged on the chain, and to his amazement, he was easily able to pull the ship out of the water!

Another legend says that when the Romans were besieging the Greek city of Syracuse, the Greeks made good use of this machine designed by Archimedes. They lowered huge claws or hooks into the sea, and picked up attacking Roman ships. Then they would lift them up and dangle them in the air, or let them drop and smash to pieces on the rocks below!

Actually, Archimedes did his most

important work in the field of mathematics. In those days, no one had ever been able to measure the exact area of a circle. Archimedes found a surprisingly accurate way to do it. He also wrote brilliant books about figures that you will study when you take geometry in school — the cone, the spiral, the parabola, the plane, the sphere and the cylinder.

His book on measuring the area and the volume of spheres and cylinders was a masterpiece. Archimedes considered it his most important work. In fact, he was so proud of this accomplishment that he asked his friends to mark his tombstone with the figure of a sphere inside a cylinder.

In 212 B.C. the Romans finally succeeded in capturing the city of Syracuse, which Archimedes had so gallantly defended with his military machines. Marcellus, the victorious Roman general, gave orders that the great scientist should not be harmed.

Archimedes was sitting in the market place or in his study, working out a mathematical problem, when a drunken Roman soldier killed him with his sword. So ended the long life of Archimedes, one of the world's greatest scientists.



Is it truth or legend? The story is told that Archimedes was sitting in the market place, or in his study in Syracuse, absorbed in the solution of a mathematical problem he had drawn in sand. He resented the interruption of a Roman soldier, and said "Don't disturb my circles." Archimedes was killed by the soldier, who was angered at the rebuke.



Nicolaus Copernicus

(1473-1543)

What did he find out about the solar system?

When you wake up early in the morning, the sun seems to be rising in the east. In the evening it appears to be going down in the west. Has the sun really moved? It certainly appears that way. Throughout history, until a Polish astronomer named Nicolaus Copernicus (Co-pur-nik-us) proved differently, most people thought the sun *did* move around the earth.

"Seeing is believing," people said. "The Earth is the centre of the Universe." And that settled the matter, or so people thought.

In the year 1499, when he was 26 years old, Copernicus became an astronomy professor at the University of Rome in Italy. He was a very intelligent young man who had studied in five different universities, and was qualified to be a teacher, a lawyer or a doctor. In his astronomy classes, he began by teaching his students the old theory put forth by a Greek star-gazer named Ptolemy, nearly 1350 years before.

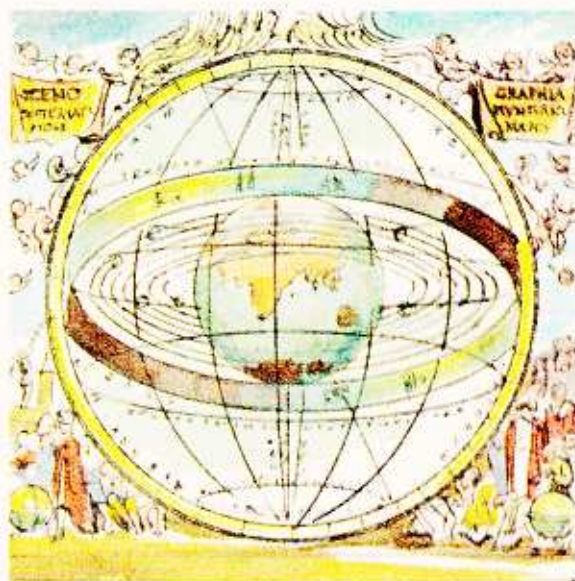
"The whole universe revolves around the earth," he told them.

But even as Copernicus was teaching Ptolemy's theory, his mind was rebelling against it. It just didn't make sense to him. It left so many things unexplained. Why did the stars move at a different speed from the sun and moon?

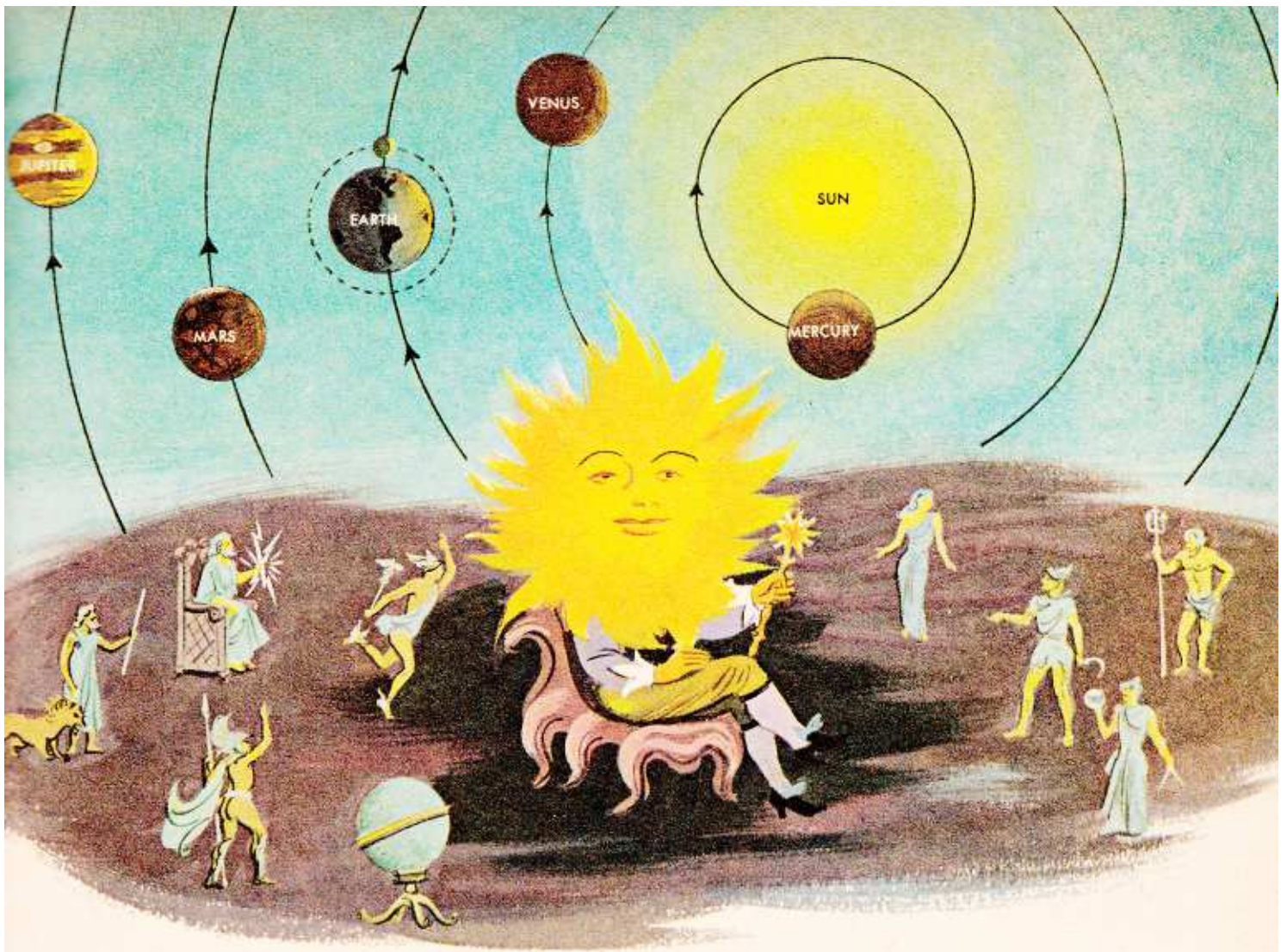
Why did some of the stars seem to wander around in the sky? Could there be something wrong with Ptolemy's theory? If it was wrong, he didn't want to go on teaching it.

As he studied the subject, Copernicus found that a few wise men before him had also doubted the Ptolemaic Theory. They thought the *sun*, not the earth, was the centre of the universe. But none of them had been able to show convincing proof. As a result, Ptolemy's theory had been accepted as correct by the Church and by most of the great thinkers of Copernicus' time.

But what if those other men had been right? Wouldn't that explain all the questions that were bothering Copernicus? He decided to give up teaching and delve more deeply into the science



About 150 A.D., Ptolemy, the famous Egyptian-born Greek astronomer, taught that the earth was the centre of the universe.



The Copernican solar system.

of astronomy. He became a priest, expecting that this work would leave him plenty of free time for his studies. Instead, he was busier than ever.

Copernicus was put in charge of the cathedral in the tiny mountain village of Frauenberg, Poland. As a priest, he conducted the religious services of the church. As a doctor, he took care of all the sick people of his parish. As an inventor, he devised a dam and a mill that would bring water into the village homes from a river two miles below. He worked out a new money system for the Polish government. And, to help the Church keep track of its holy days, he created a very accurate calendar.

All these activities would have been a full-time job for most men. But the amazing Nicolaus Copernicus somehow managed to find time for his favourite subject, astronomy. Since the telescope was not invented till many years after his death, he had to rely on his own eyes to study the movements of the heavenly bodies. He cut slits in the roof of his study in the cathedral tower. As he sat there in the dark, he could see the stars passing across the slits. He kept track of their position in the sky and charted how fast they seemed to be moving.

Copernicus made accurate records of everything he observed. Then he worked out mathematical formulas to explain

what he saw. Little by little he began to gather the facts that one day would make up the Copernican Theory of Astronomy — the one we accept as true today. It took Copernicus nearly forty years to complete his studies. When he had finished, he had proved that the Ptolemaic Theory was wrong.

This, said Copernicus, is what really happens: The sun is the centre of our universe. The earth is a planet that revolves around the sun. The word "planet" comes from a Latin word meaning "wanderer."

There are other planets in addition to the earth. They, too, revolve around the sun. Copernicus knew five of them: Mercury, Venus, Mars, Jupiter and Saturn. The other three, Uranus, Neptune and Pluto, were not discovered until much later. These nine planets make up what is called our solar system. "Solar," from Latin, means "sun."

One of the most important points of the Copernican Theory is this: while the earth revolves around the sun once every year, at the same time it is rotating rapidly on its own axis (an imaginary line that runs through the middle of the earth like a stick through a lollipop). When our side of the earth is near the sun, it is daytime. When we're turned away from the light of the sun, it is night time. This rotation takes 24 hours — the length of one day and one night. What about the moon? Copernicus

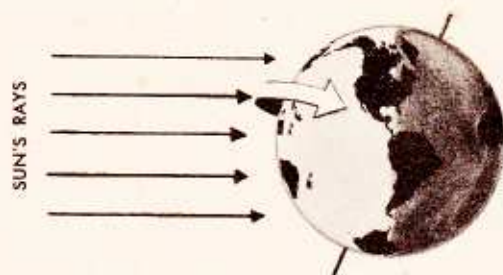
had to agree with Ptolemy about one fact: The moon does revolve around the earth, while the earth is revolving around the sun.

There is much more to the theory but these are the basic facts. The Copernican Theory corrected serious errors that had been accepted for centuries, and set the stage for our modern science of astronomy.

Copernicus wrote a book telling about his discoveries, but he kept it locked in his desk for years. He knew that people would laugh at his "new-fangled" ideas, and say that he was crazy. He also knew that the Church officially approved the old Ptolemaic Theory. As a priest, he should not disagree with the Church.

It wasn't until 1543, when he was old and near death that he finally decided to publish his book. He called it *Revolutions of the Heavenly Orbs*. A printed copy of the book arrived at his bedside just a short time before he died. Since he was seventy years old, paralyzed and nearly blind, it is doubtful that he ever saw the great book that he had spent a lifetime to prepare.

Copernicus died never knowing what a great service he had done for the world. In fact, it wasn't until 150 years later that his ideas were completely accepted. Today, more than four centuries after his death, he is considered one of the true giants in the world of science.



The earth revolves once around the sun during one year, and rotates once in 24 hours on its own axis. As the earth turns, we get day and night.

How did he show the world
that a scientist cannot
be bound by superstition?

Galileo Galilei

(1564-1642)



In the year 1583, a young college student named Galileo Galilei, (gal-ley-lay-o gal-ley-lay-ee) was kneeling in a cathedral in the Italian city of Pisa. A church worker had just lighted a hanging oil lamp, and Galileo looked up to see it swinging back and forth on the end of its chain. He noticed that although each swing or arc was shorter than the last, each swing still seemed to be taking the same length of time. Most people would not have found anything unusual in this, but Galileo had the inquiring mind of a scientist. He always wanted to know "Why?"

He conducted a series of experiments by tying a weight on the end of a string, and swinging the weight back and forth. There were no really accurate watches in those days, so Galileo used the regular beat of his pulse to time the movement of the swinging weights. He found that although the arcs gradually became shorter and shorter, each one took an equal length of time.

Galileo had discovered the principle of the pendulum. This principle is known as *isochronism*, which means "uniform in time" or "occurring at regular intervals." In later experiments, other scientists found that each arc actually takes a little less time than the one before it, due to friction or air resistance. Nevertheless, Galileo's principle of the pendulum is used in many ways: to measure the movement of the stars, and to control the timing of

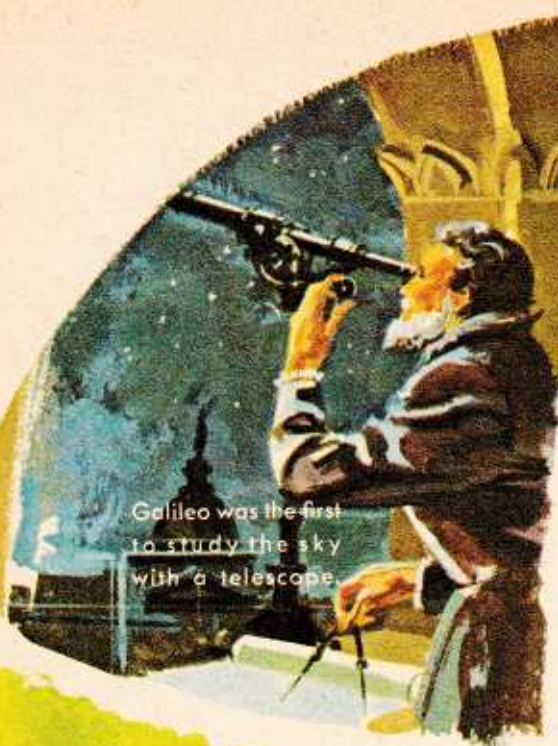
clocks, for example. His study of the pendulum was the beginning of our modern science of dynamics which deals with the laws of motion and force.

Galileo graduated from the University of Pisa in 1588, and stayed there to teach mathematics. At the age of twenty-five, he made his second great scientific discovery — one which shattered 2000 years of tradition, and earned him a great many enemies.

In those days, most so-called scientific knowledge was based on the ancient theories of the Greek philosopher Aristotle, (384-322 B.C.). He was still considered the great master of all scientific thought. Anyone who disagreed with one of Aristotle's many rules was frowned upon.

Two thousand years before, Aristotle had said that a heavy object falls faster than a light one. Galileo disagreed. According to a famous story, he decided to make a public demonstration of his own theory. He invited his fellow professors to climb to the top of the Leaning Tower of Pisa. Galileo took with him a 10 pound cannon ball and a 1 pound ball. He leaned over the railing and dropped them both at the same time. To everyone's great surprise, both balls hit the ground at the same time!

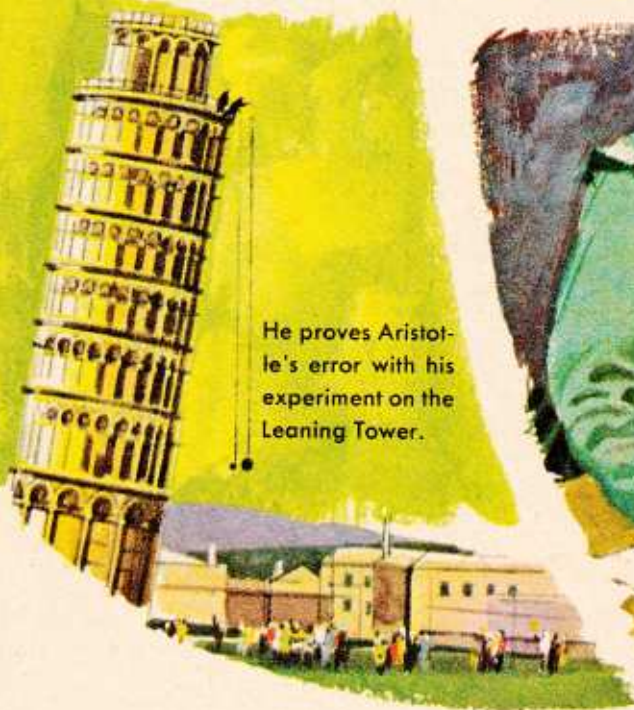
Whether or not this event actually



Galileo was the first to study the sky with a telescope.



His clue to the Laws of the Pendulum came in the cathedral of Pisa.



He proves Aristotle's error with his experiment on the Leaning Tower.



In the course of his experiments to prove that heated air expands, he re-invented the thermometer.

happened, Galileo did discover a very important principle in the science of physics: the speed or velocity of falling bodies is independent of their weight. But more than that, he demonstrated that a true scientist must test every rule, instead of accepting what somebody else tells him. For 2000 years, people

had believed Aristotle's idea about falling bodies, but nobody had tested it until Galileo came along.

Yet, imagine Galileo's disappointment when, in spite of the evidence, his fellow professors said he was wrong and went back to teaching Aristotle's old theory. They criticized Galileo, and

demanding that Galileo leave the University. Finally after three miserable years, Galileo was forced to resign.

Fortunately, some friends came to his aid, and in 1592 he became a professor at the University of Padua, in Italy. There he was able to continue his experiments without being tormented and criticized. In the years he taught at Padua, Galileo produced a remarkable number of new scientific theories and inventions. He re-invented the thermometer, which had been invented by a Greek scientist in the third century, and then had been completely forgotten. The most important of his inventions was a telescope, named for the Latin words that mean "far-seeing." Galileo's telescope was not the first, but it was the best ever produced until that time. It made distant objects appear 33 times larger than they appeared to the naked eye.

Galileo was the first person to systematically study the sky through a tele-

scope. He saw that the moon had mountains and valleys on its surface. He saw that the moon and the planets did not give off their own light, but reflected the light of the sun. He found that the Milky Way was made up of millions of tiny stars. He discovered four moons revolving around Jupiter.

As he studied, he began to reject the old theories that said the earth was the centre of the universe, with the sun and stars revolving around it. Many years before, in 1543, the Polish astronomer Copernicus had published his great book, declaring that the *sun* is actually the centre of our universe, and that the earth and planets move around the sun. This Copernican Theory had been condemned by the Church and almost forgotten, until Galileo publicly declared that he agreed with it.

Galileo's declaration stirred up a terrific storm of protest. Outraged officials of the Catholic Church again condemned the Copernican Theory, and



Galileo was the first to study the sky with a telescope.

banned all books which approved of it. (Copernicus had been dead for over seventy years by then!) Galileo was forced to promise Pope Paul V not to hold, teach or defend the condemned Copernican Theory. Galileo agreed, unwillingly, and went back home, a very unhappy scientist.

But because he *was* a scientist, to whom truth was the most important thing in the world, Galileo found it impossible to keep silent for very long. In 1632 he published a book in which he said Copernicus was correct, and explained his theory in greater detail.

Now he was really in trouble! He had openly defied the ruling of the Church. This was a very serious crime. Men had been burned at the stake for less. He was summoned to appear in Rome before a powerful group of church officials called the Inquisition. If the Inquisition found him guilty of disobeying Church rules, they could punish him by sending him to prison, torturing him or putting him to death.

Galileo was nearly seventy years old

and in poor health when his trial began. At first he said he was not guilty. But under threat of torture he finally gave in, and said he was wrong in agreeing with Copernicus that the earth moved around the sun. He begged forgiveness for his error.

The Inquisition was lenient with the great scientist. Instead of the death penalty, it sentenced him to spend the rest of his life as a prisoner in his own home. He was forbidden to conduct any more experiments or write any more books.

But Galileo was defiant to the end. He continued his experiments and wrote two very important books before he died in 1642.

Today we honour Galileo as a brilliant and courageous scientist who contributed a great deal to mankind. He showed the world that scientists must be free to discard old ideas and accept new ones and that they cannot be bound by superstitions or traditions. As Galileo put it, "Freely to question and freely to answer" must be the aim of all men of science.



William Harvey

(1578-1657)

Why is his work considered a major scientific breakthrough in medicine?

In many ways, scientists and detectives are alike. They both set out to solve a certain problem or mystery. First

they have to find some clues. They study the clues until they have a theory. Then they snoop and pry and ask questions until they have absolute proof that their theory is right. Only then are they convinced that they have solved the mystery.



Anatomy class at Cambridge University, England, at the end of the sixteenth century.

You might say that Dr. William Harvey was a medical detective. The mystery he solved was that of how the blood moves in the human body. He spent thirty years following clues, asking questions and performing experiments. Finally, when he was absolutely sure he was right, he announced the solution to the problem.

This is the story of William Harvey and his medical detective work. He was a bright young Englishman who entered Cambridge University in 1593, when he was only fifteen years old. One of his favourite courses was anatomy, the study of how the human body is constructed. He became especially interested in the arteries and veins through which our blood flows.

In those days, no one knew very much about blood and the way it moves through the body. Some people thought blood was manufactured by the liver. Others said it came from the stomach. A famous doctor said there were two kinds of blood: one moved back and forth through the large blood vessels called arteries, the other flowed

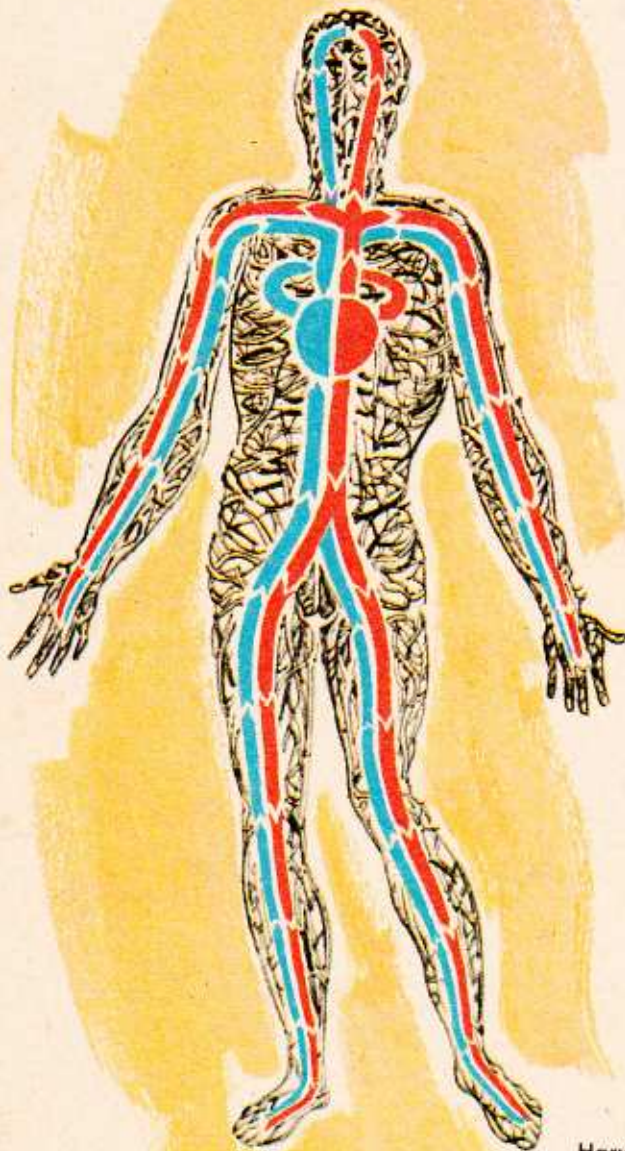
through the smaller blood vessels called veins. Every anatomy teacher taught a different theory.

William Harvey was graduated from Cambridge with excellent grades, but he was not satisfied with what he had learned. Of all those different ideas about how the blood moves, which was false, which true? He probably didn't realize it then, but he had found the mystery that would make him wonder and work for many years until he had finally solved it.

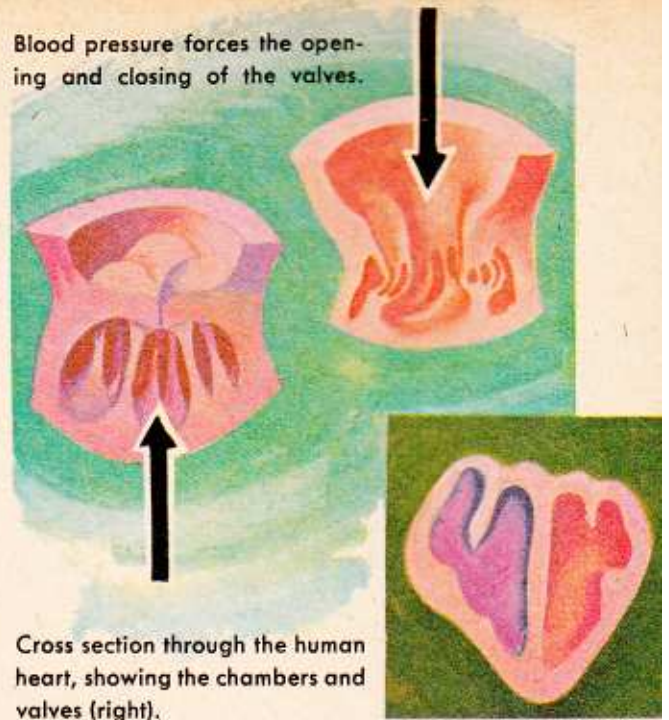
He went on to study medicine at the University of Padua, where the great Galileo taught astronomy. There, he was fortunate enough to have a brilliant surgeon named Fabricius as his anatomy teacher. Fabricius had recently made the discovery that the veins have little "doors" or valves in them. This was as far as Fabricius had gone in his research, but it was enough to give William Harvey the clue he needed. He decided that he had to find out more about those little valves, and what their purpose was. Whenever he had a chance, he would dissect the bodies of

birds, frogs or rabbits, and study their blood vessels. He found that the valves in the veins always open *toward* the heart. He also found that the arteries have valves that always open *away* from the heart.

It wasn't until he began experimenting with living animals that he found his most important clue: the blood in the veins always flows *toward* the heart, and the blood in the arteries always flows *away* from the heart. The valves open only one way, to keep the blood flowing in the proper direction. Now he was getting somewhere!



Blood pressure forces the opening and closing of the valves.



Cross section through the human heart, showing the chambers and valves (right).

By this time Harvey had graduated from college as a full-fledged doctor. He opened an office in London, and before long he had as many patients as he could take care of. Now he had a chance to observe the hearts and blood of *people*, as well as animals.

Dr. Harvey took careful notes about everything he saw. In his free time, he continued to experiment with animals. He began to formulate his theory. But he was a born scientist; before he came to any conclusions, he wanted plenty of evidence. Years went by while he continued his search.

The heart, he found, is a hollow muscle about the size of your fist. It works like a pump. When it contracts or squeezes itself together, it pumps about 2 ounces of blood into the arteries. Then it relaxes, and gets larger, until the next contraction. When the doctor "takes your pulse" he is counting the "thumps" as your heart contracts to pump out blood. Depending on age and sex, the pulse is 72-90 beats per minute.

The normal adult heart beats or

Harvey's theory of the circulation of the blood was not accepted without a struggle.

pumps between 60 and 90 times per minute. William Harvey did some arithmetic and found that a heart must pump over 65 gallons of blood every hour! This was his final clue. The body obviously cannot manufacture and get rid of 65 gallons of blood every hour. He knew that the average man has about 4 or 5 quarts of blood in his body. What must happen is this: the same blood moves through the body in a kind of circle.

William Harvey finally had his theory. The blood *circulates*. It goes from the heart into the arteries, to the veins and back to the heart again. The one-way valves in the arteries make the blood flow away from the heart. The valves in the veins let the blood flow back toward the heart.

Again and again he examined hearts and arteries and veins until he was completely satisfied that his theory was right. Then he began to discuss his ideas with other doctors. And not until 12 years after that, did he finally gather

together all his research and publish it in a famous book called *Treatise on the Motion of the Heart and Blood*.

As he expected, the book caused a great commotion in the medical world. Remember, it appeared early in the 17th century when people still believed in witches and demons. They were slow to accept new ideas. Even the well-educated doctors tended to cling to old superstitions. But the truth finally won out, and William Harvey's theory of blood circulation was accepted as being scientifically correct.

Today, doctors often take blood from a healthy person's arteries and transfer it to a sick person to give him strength. There are marvellous machines that keep the blood circulating automatically, while the doctor operates on the heart. None of these life-saving techniques would have been possible without the remarkable detective work of William Harvey — a fine doctor and a great scientist.

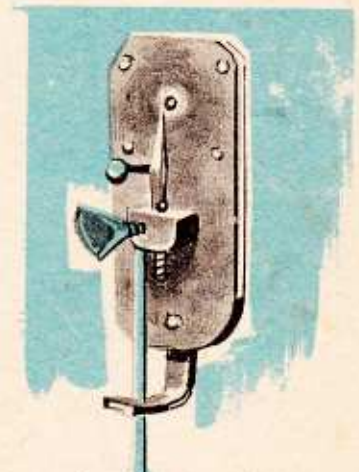
Anton Van Leeuwenhoek

(1632-1723)

How did the owner of a draper's shop become a member of the Royal Society?

Anton van Leeuwenhoek (*lay-ven-hook*) was a quiet little Dutchman who ran a small draper's shop in the city of Delft, Holland. The only unusual thing about him was his hobby. He spent all his spare time making magnifying glasses!

One of Leeuwenhoek's first microscopes.



In those days, even the finest glass lenses, ground by the best professional lens-makers, could magnify things only ten times. They were used mainly for reading, by people with weak eyesight.

But Leeuwenhoek was not satisfied with the store-bought lenses. He knew very well he could make better ones himself. He worked hard in his store in the daytime. At night, he would hurry home and spend long hours over his work table, grinding and polishing tiny bits of glass no bigger than a large dot.

He made hundreds and hundreds of these lenses. His skill improved with practice, and finally he was able to make lenses that could magnify a flea so that it looked 150 times as large as it actually was! Leeuwenhoek made gold or silver frames for his lenses, and sometimes he attached handles to them so that he could carry them around and examine things through them.

Then he thought of something better. He mounted a lens on a little frame and put a mirror beneath it to reflect the light up into the lens. On a strip of clear glass between the lens and the mirror, he placed whatever he wanted to examine: the eye of a fly, a speck of pepper or a bit of skin. The magnifying glass was now a microscope. Forty years before he was born, another Dutch lens-maker had perfected a microscope with two lenses, but Leeuwenhoek's single lens machine was far better and easier to use.

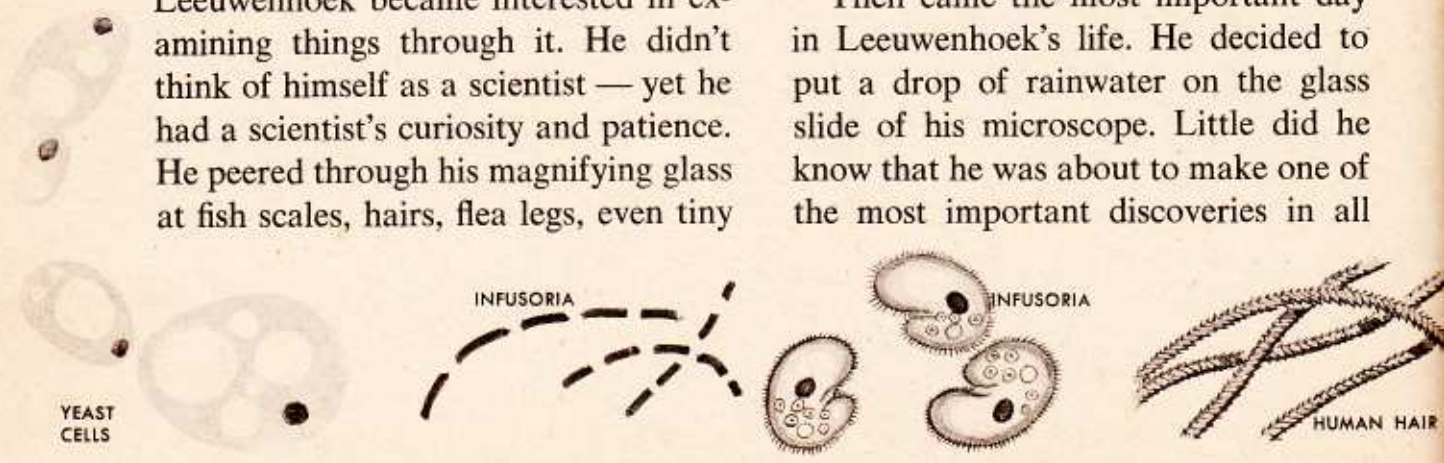
Now that he had succeeded in making the finest microscope in the country, Leeuwenhoek became interested in examining things through it. He didn't think of himself as a scientist — yet he had a scientist's curiosity and patience. He peered through his magnifying glass at fish scales, hairs, flea legs, even tiny

specks of dust. Hardly anything escaped his gaze. And he examined everything with great care. He didn't look at just one human hair; he looked at hundreds of them. Not till he was sure that all hairs were constructed exactly alike did he finally make a drawing of what he saw, and label it "human hair."

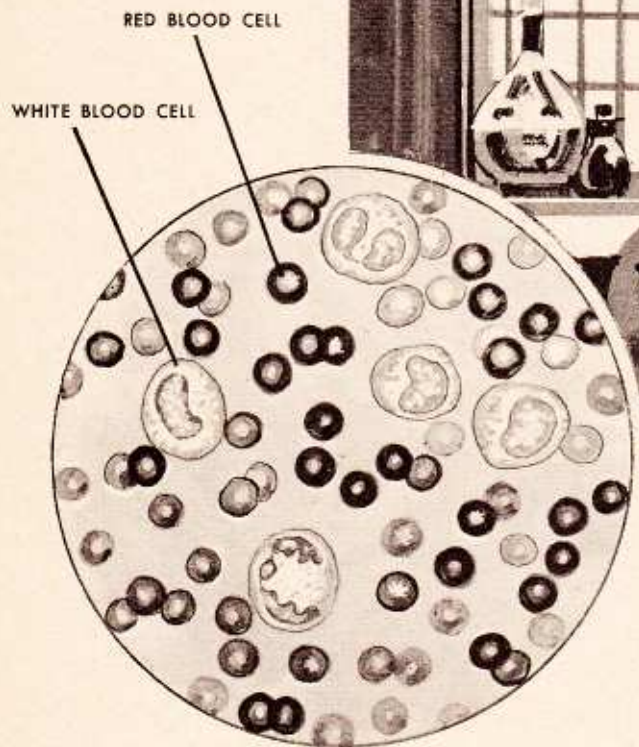
In England, at that time, a group of well-known scientists had formed a club called the Royal Society. Some of the most famous members were the chemist, Robert Boyle, the inventor, Robert Hooke, and the great Isaac Newton. One of Leeuwenhoek's friends in the city of Delft was an honorary member of the Royal Society, and he suggested that Leeuwenhoek write to the English scientists and tell them of his findings.

Leeuwenhoek was glad to have somebody to confide in because most of the people in Delft thought he was slightly crazy. The first letter he wrote had the title "A Specimen of some Observations made by a microscope contrived by Mr. Leeuwenhoek, concerning Mould upon the Skin, Flesh, etc.; the Sting of a Bee, etc." The learned gentlemen of the Royal Society were quite interested, and asked if he would write again when he made any new discoveries. In the next fifty years they received hundreds of long, chatty letters from the little Dutch lens-maker.

Then came the most important day in Leeuwenhoek's life. He decided to put a drop of rainwater on the glass slide of his microscope. Little did he know that he was about to make one of the most important discoveries in all



Leeuwenhoek, right, in his study in Delft examining a drop of blood under the microscope which you saw on page 17. Below, the red and white blood corpuscles he detected.



history. For there, the amazed Leeuwenhoek saw dozens and dozens of what he called "little beasties" swimming and wiggling in that tiny drop of water. They were so small, he said, that you could put a million of them on a coarse grain of sand!

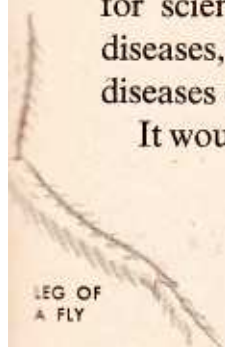
This simple storekeeper was the first man in history to see the tiny germs we call microbes or bacteria. His discovery would one day change the entire course of medical science, and make it possible for scientists and doctors to diagnose diseases, treat diseases and even prevent diseases caused by bacteria.

It would have been easy for Leeuwen-

hoek to jump to the conclusion that microbes fell from the sky in rainwater. But a true scientist demands proof. He carefully washed a dish and collected some clean rainwater. He examined it under his microscope and found no bacteria in it. But after the dishful of water had collected dust for a few days, Leeuwenhoek found thousands of the "little animalcules."

That still wasn't enough proof for the stubborn Dutchman. He examined water from puddles, from rooftops, from lakes, from streams, everywhere he could find it. And after weeks of study, he came to a conclusion. Microbes are in the air all about us, he said. They float down on particles of dust. And he was correct.

Leeuwenhoek continued to peer at things through his wonderful lenses. One day he pricked his finger and curiously examined a drop of blood. Thus, he was the first man to see and describe



EYE OF
A FLY



red blood corpuscles, which are tiny cells that float in the blood and give it its red colour.

He scraped the film from his teeth and found that it was filled with bacteria, too. Then he made a very interesting discovery. After he had swallowed steaming hot coffee, certain kinds of bacteria on his teeth were no longer alive. This was the first proof that heat can kill bacteria, and it led to the cleansing process we know as "sterilization."

One day he looked at the tail of a tiny fish, and saw for the first time the tiny blood vessels that carry our blood from the arteries to the veins. These blood vessels are so thin they are called "capillaries" from the Latin word for "hairlike." In the last chapter you learned how William Harvey discovered that our blood circulates away from the heart in our arteries, and back to the heart in our veins. But he did not know how the blood got from the arteries to the veins. Leeuwenhoek answered this question for him!

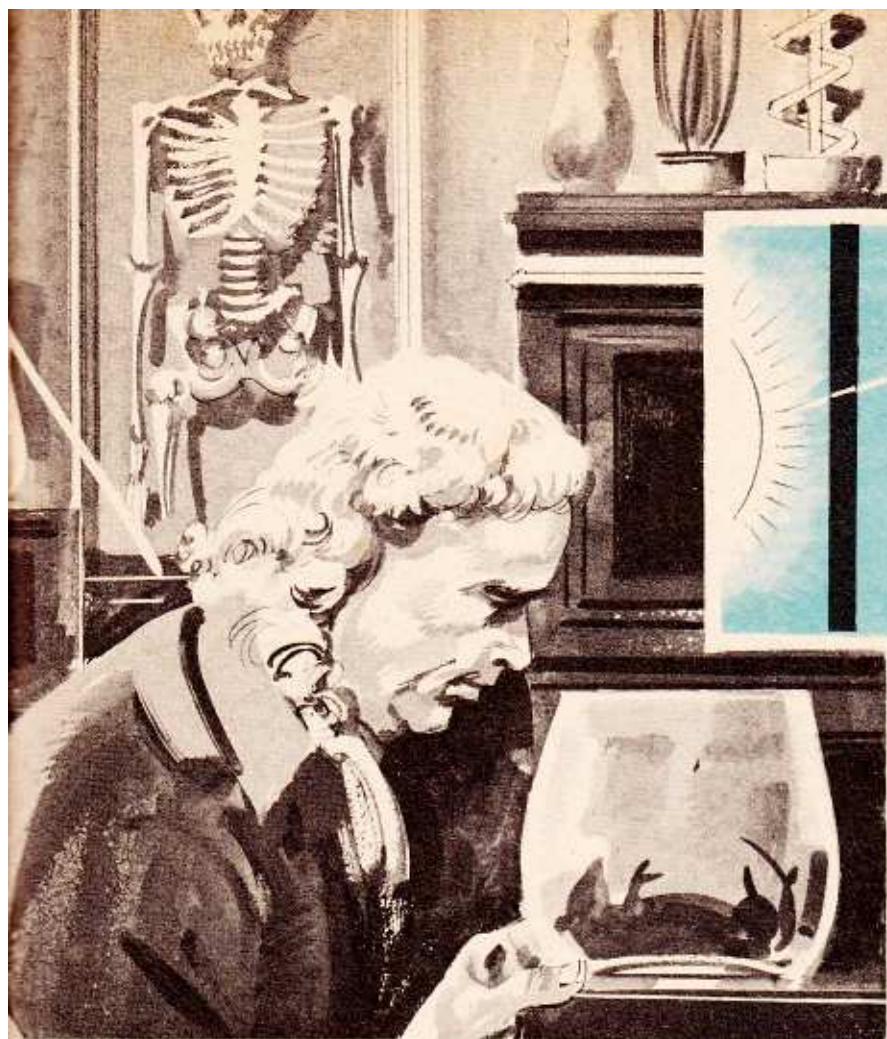
As the years went by, Leeuwenhoek continued writing to the Royal Society in England. When they received his reports they tried to duplicate his experiments. By 1680 they were so impressed by his genius that they made him an honorary member of their exclusive society.

Leeuwenhoek was becoming a famous man, much to his dismay. He had such distinguished visitors as the Czar of Russia, Peter the Great, and the Queen of England. Everybody wanted to look through his famous microscope. But he preferred to be left alone so that he could do his work.



He was nearly eighty when he made one of his most remarkable discoveries. He was studying mussels, the shellfish that grew in the canals of Delft. He kept one of them in a glass of water for many days, and was surprised to note that bacteria in the water were eating it up. Thus Leeuwenhoek showed the world that microbes or bacteria can destroy living things many times their own size! He also proved that some bacteria can be useful by destroying unwanted refuse and garbage.

Finally, at the age of ninety-one, Anton van Leeuwenhoek put aside his microscope and closed his weary eyes forever. Although he was a simple man, untrained and uneducated, his persistence made him a great pioneer in the science of bacteriology.



A lot of research in various fields was conducted simultaneously in the Science Academies of Newton's time.

Newton discovered how a prism breaks up light into the colours of the rainbow.



Isaac Newton

(1642-1727)

Why was he once called the "greatest genius of all time"?

1 Almost everyone has heard the famous story about how Isaac Newton discovered the Law of Gravity while sitting under an apple tree. Unlike many historical legends, this one happens to be true. An apple fell from the tree and narrowly missed hitting him on the head. Because he was a scientist, Newton immediately began asking himself questions. Why did the apple fall down instead of up? If apples and other objects fall down, why doesn't the moon fall down? When Newton finally worked out the answers to these questions, several years later, he was able to write a

formula explaining the great basic Law of Gravity that governs the universe.)

At that time Isaac Newton was 23 years old, having been born the same year Galileo died. He was in his fourth year at Cambridge University in London. But the Great Plague was killing thousands of Londoners, and the mayor had closed all of the schools and the students were sent home.

2 Newton went to his mother's farm. During the 18 months that followed, he accomplished more than most scientists do in a whole lifetime. He began investigating the Law of Gravity. He invented

calculus, a new system of mathematics. He made an extensive study of light and colour. He discovered the laws of the tides. He formulated certain laws about motion that later became the basis of a new science called mechanics.) All this in a year and a half! It's easy to see why Newton has been called the "greatest genius of all time.")

But let's get back to that falling apple. The early scientists knew that objects fell to earth because they were pulled down by a force in the earth called gravity. But Newton wasn't satisfied with this explanation. He decided that the earth is not the only object that has a gravitational force. It exists in all objects, big and small. The Law of Gravity is always at work, on all things. The pull of the earth's gravitational force is what makes you fall *down* toward the earth when you stumble, and it is what keeps you from flying up in the air when you walk.) The sun's gravitational force pulls the earth and keeps it from flying off into outer space as it revolves around the sun.

3 (As Newton said later in his great book, *Principia*, "Every particle of matter in the universe is attracted by every other particle in the universe." He went on to say that the whole world is held together by this force, and the force varies according to the size of the objects and the distance between them.) This force can be accurately figured by using Newton's mathematical formulas.

Once these basic facts were discovered, men were able to make great progress in all the sciences. Astronomers could determine the weight of the sun and the planets and predict their move-

ments. Since they now knew that gravity of the moon and sun caused the tides in the earth's seas, they could predict when the tides would rise and fall, and how high they would be.

Because the pull of gravity causes things to move, Newton found that he couldn't very well explain gravity without explaining motion. This he did with his Laws of Motion—three great mathematical formulas that explain the forces that make things move, the forces that make things stop moving, and the directions and rates of movement.

While he was still vacationing at his mother's farm, Isaac Newton turned his attention to the mystery of light. He held a three-sided piece of glass called a prism so that a beam of sunlight could shine through it. He found that the white light rays bent as they passed through the glass, and were separated into rays of seven different colours. These are the colours of the rainbow, called the *spectrum*—red, orange, yellow, green, blue, indigo and violet.

Remember, Newton made all these vital discoveries in a period of 18 months. He did not publish them immediately, because there was a great deal of work to be done on them. Like all true scientists, he wanted to make sure he was right before he made any public announcement of his findings. When the Great Plague was finally over, he went back to London to finish college, and to continue his experiments.

Newton spent three more years investigating the nature of light. He made discoveries that proved to be of great importance in the science of optics, which deals with light and vision and



the making of lenses for reading glasses, telescopes and microscopes.

He invented the first telescope that reflected light from a mirror, instead



Newton discovered that the blurred image produced by early telescopes was caused by the breaking up of the light into colour on the fringes of the glass lenses. He devised the reflecting telescope, which focuses the light from a star with the help of a metal mirror, thus avoiding the colour fringes.

of through a glass lens. Newton's telescope had a 1-inch mirror. Today at Mt. Palomar University in California, there is a reflecting telescope with a 200-inch mirror, which is built according to Newton's original principle.

Next, the great man returned to his main interest, the study of gravity and motion. He spent almost twenty years testing, proving and improving his early theories. (It wasn't until 1687, when he

was 45 years old, that he finally published his Law of Gravitation and three Laws of Motion in his *Principia*. This book presented so much new scientific knowledge that it changed the world forever.)

In public recognition of his work, the British government gave him the post of Warden of the Mint in 1696. Four years later he became Master of the Mint, a position he held the rest of his life. That same year he was elected to the French Academy of Science — a great honour for an Englishman.

In 1703 he became President of the British Royal Society. And in 1705 he became the first British Scientist to be knighted. From then on he was *Sir Isaac Newton*, and he was very proud of his new title.

(Newton lived to be 85 years old. When he died he was buried in Westminster Abbey in London, in the company of the most honoured names in the history of England.)

What made him the Pioneer of the Electrical Age?

Michael Faraday

(1791-1867)



How many times have you used electricity today? Here are a few of the electrical appliances you may have switched on: the lights, the radio, the stove, the toaster, the refrigerator, the television, the washing machine.

For all these wonderful things and many more, you owe a "thank you" to an English scientist named Michael

Faraday, who is known as the pioneer of the Electrical Age.

Of course, Faraday was not the first to discover electricity. The early Greeks

While employed in a bookshop young Faraday read every book on science he could find.



learned they could get an electrical spark by rubbing a piece of amber. Amber is hardened yellow-brown resin from certain pine trees. The Greek name for amber was "electron," from which we get the word "electricity."

In 1752 the American inventor Benjamin Franklin performed his famous kite-flying experiment, and discovered that lightning is electricity.

In 1800 an Italian scientist named Volta invented the first electric battery, which produced a continuous flow of electricity.

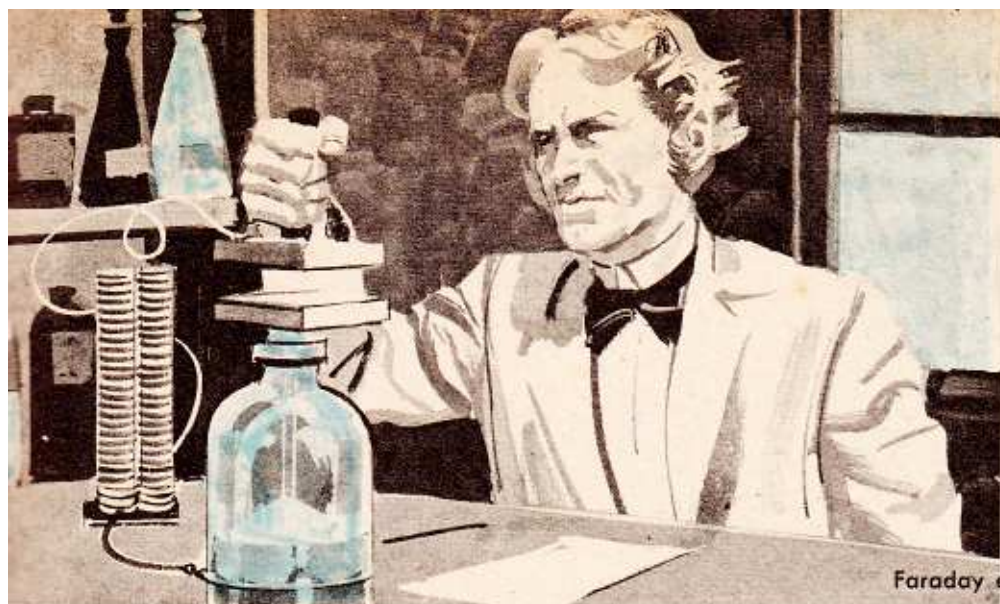
But the man who really put electricity to work was Michael Faraday. He showed the world how to make electricity run a motor. Then he showed us how to make a motor produce electricity. His experiments were the beginning of the Electrical Age.

Michael Faraday was the son of a blacksmith. His father was too poor to send him to school, so at the age of thirteen Michael found a job in a bookshop. There he began reading all the scientific books he could find on the shelves. Whenever he could scrape a few pennies together, he would attend lectures by England's greatest scientists.

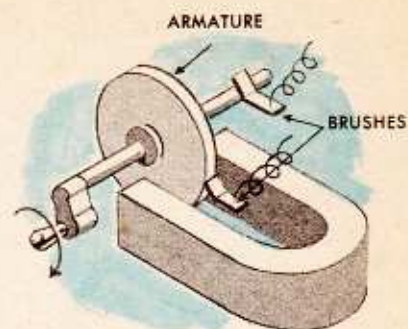
When Faraday was twenty-one he went to a series of lectures by a very famous chemist, Sir Humphry Davy. Faraday took careful notes from the speeches. Then he sent the notes to Sir Humphry. The chemist was so pleased with the accuracy of the notes, he offered the young man a job as an assistant in his laboratory.

At first Faraday did only the lowly jobs, such as washing bottles and cleaning the laboratory. But all the while he kept his eyes and ears open. Whenever he got a chance, he would try some experiments of his own.

Electricity was his special interest. Scientists already knew that if they passed electricity through certain fluids, they could separate the fluid into the substances of which it was made. For instance an electric current sent through water splits it into oxygen and hydrogen. If you send an electric current through a solution of silver nitrate, the pure silver will separate out. This process is called electrolysis. Faraday conducted many electrolysis experiments. He developed a formula for the process which states that the amount of material decomposed during electrolysis is



Faraday experimenting with electricity.



Faraday's electrical generator.

always in proportion to the amount of electricity used. This is called Faraday's Law of Electrolysis.

In 1821 Faraday built the first electric motor. It was a very simple motor, just a copper rod made to rotate by sending electricity through it from a battery. Although it was too small to do any practical work, it was a great invention. One day it would be improved and developed into motors that run huge machines in our factories.

Faraday's experiments were attracting the attention of the scientific world by now, and he was gaining an excellent reputation. In 1824 he was made a professor at the Royal Institute in London. The blacksmith's boy had come a long way. In 1831 Michael Faraday reversed the process by which he had made an electric motor. Instead of using electricity to produce motion or mechanical energy, he used motion to produce electricity. He started with a common magnet, which is a piece of metal that has the power to attract certain other metals. Magnets can be made of steel, iron, cobalt or nickel. Faraday's magnet was made of iron.

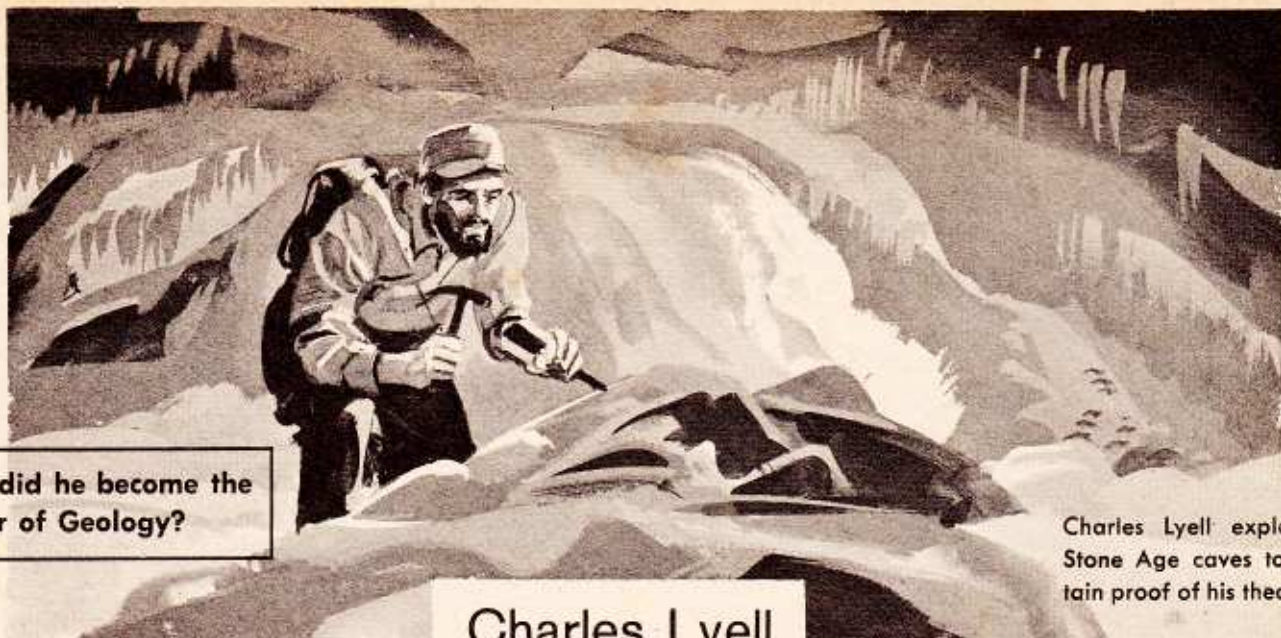
The magnetic force of a magnet ex-

tends out into the space around it. The area of this force is called the magnetic field. It is invisible. Faraday found that he could produce electricity simply by passing a piece of copper through this magnetic field. Once he had discovered this fact, he was able to get a continuous flow of electricity by passing copper through the magnetic field at a very fast rate of speed.

Faraday's first generator was a copper disc suspended between the two ends of a large, horseshoe-shaped magnet. A hand crank supplied the power to turn the disc. As the disc rotated rapidly through the magnetic field between the ends of the magnet, electricity was generated. It passed out through wires connected to two small copper "brushes" shown in the illustration.

This principle is still used today in the gigantic generators at Hoover Dam, Niagara Falls and other great power plants where electricity is generated.

Michael Faraday conducted many experiments and made many important discoveries. But he will be remembered especially as the man who converted electricity into power and gave us the electric motor and generator.



How did he become the
Father of Geology?

Charles Lyell exploring
Stone Age caves to ob-
tain proof of his theories.

Charles Lyell

(1797-1875)

When Charles Lyell was born in Scotland, in 1797, there were very few people interested in the subject of geology. Most people knew that the earth was round. Some of them thought the earth was hollow, but this was only an old legend, and nobody could prove or disprove it.

The average man believed the earth began in the year 4004 B.C., because a 17th century Archbishop once said so. But the ancient Egyptians were alive many centuries before 4004 B.C., so this date was obviously wrong.

It wasn't until Charles Lyell wrote a book called *Principles of Geology* in 1830 that geology became a true science. (A science is a body of facts or knowledge gained by systematic study.)

Charles Lyell came from a wealthy family. He attended the finest private schools in Scotland. His father wanted him to be a lawyer, so he went to London and studied law at Oxford University. He opened his own law office in London, but after two years he decided he would rather do something else.

What Charles Lyell really enjoyed was to climb mountains and examine the unusual rock formations. Sometimes he found plant or animal fossils imbedded in the rocks. Fossils are imprints or skeletons of things that had lived many years ago. He was curious to know how the fossils got there, and how old they were. Lyell was also interested in finding out what made the earth's surface so rough and irregular, with huge heaps of rocks sticking up, and ragged cliffs where the earth seemed to be broken off. The common explanation was that at some time in the past, one great upheaval or earthquake had wrenched and twisted the earth and caused all the peaks and valleys and craters to be formed.

These explanations did not sound convincing to Charles Lyell. He was even more sceptical after he read an old, forgotten book written in 1785 by James Hutton. Hutton proposed the theory that the earth was far older than anyone imagined, and that it had always been in a constant state of change.

The peaks and valleys, rivers and volcanoes were not formed by just one terrible catastrophe a few thousand years ago. They were a result of thousands, maybe millions of years of rain, snow, wind and tides acting on the earth and moving things around. James Hutton's ideas were not accepted by the scientists of his day. But Charles Lyell was impressed. He believed Hutton was on the right track.

He spent many years exploring the extinct volcanoes, caverns, mountains, dried up lake beds and forests of Europe. He collected every sort of fossil he could find.

He became convinced that Hutton's old theory was the correct one. The earth was not thousands of years old, but millions. And he believed that the changes in the earth's crust were not brought about by one tremendous convulsion, but by millions of years of slow, natural changes.

These are some of the things that change the face of the earth, said Lyell: rainfall, windstorms, sandstorms, tides and currents, earthquakes, rivers that carry along sand and mud, springs that bring up minerals from deep down in the earth. As new layers of earth are built up into mountains, or old mountains are broken down, plant and animal skeletons are caught and preserved there. As the years go by they are buried under deep layers of rock or sand or mud.

In 1830 Lyell published the first volume of his great book, *Principles of Geology*. Two more volumes followed in 1832 and 1833. They contained convincing proof of his theories about the

age of the earth and how it changes through the years. His books were immediately successful and Lyell found himself a famous man. Because of him, geology had a firm scientific foundation to stand on.

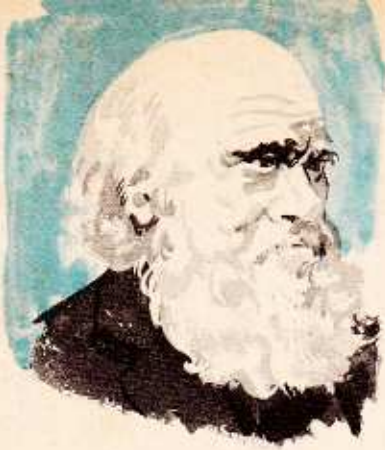
In 1841, he was invited to the United States to give twelve lectures in Boston. So many people came to hear him that he had to deliver the lectures twice. While he was in the United States, he visited Niagara Falls and worked out the rate at which the waterfalls were wearing away the huge rocky cliffs. He went to see the Mississippi River, and worked out how much mud the river deposits each year at its delta, the place where the river enters the Gulf of Mexico.

In 1848 Lyell was knighted by Queen Victoria. Later he was made a Baronet.

Principles of Geology had a great influence on the naturalist, Charles Darwin. If the crust of the earth has been slowly changing down through the centuries, perhaps man, too, has been slowly changing or evolving, thought Darwin. After Darwin published his famous Theory of Evolution, Lyell became one of his most enthusiastic supporters. He even gave up geology, temporarily, to write a book called *The Antiquity of Man*, which listed all the arguments proving that man appeared on earth millions of years ago in a form quite different from the way he looks today.

But Charles Lyell's fame rests on his work in geology. From the principles he established, modern geology has become an important and growing science.





Charles Darwin

(1809-1882)

What is the
"survival of the fittest"?

On a cold, windy day in December, 1831, an old ship called the *Beagle* sailed out of the harbour at Portsmouth, England. Huddled in a tiny cabin, already beginning to feel seasick, was a 22 year old student named Charles Darwin.

The *Beagle* was going on a five year scientific expedition for the British government. The men on board were to explore the coastline and islands of South America, Australia and New Zealand, and make new accurate maps. Charles Darwin went along as an unpaid assistant. His job was to study the plants and animals in the places they visited.

Life aboard a crowded sailing ship was very hard. The food was terrible. Darwin was constantly seasick. The only time he was really happy was when the *Beagle* landed and he could go ashore to collect specimens of plants, insects, rocks and small animals. Since the *Beagle* was already crowded, he had to put his specimens in crates and send them back home to England.

Darwin's health was permanently affected by the miserable conditions on board the *Beagle*, but he never regretted making the trip. He later said "It was by far the most important event of my life, and determined my whole career."

The career of Charles Darwin turned out to be a most unusual one. His theories on the origin and development of living things created the biggest sensation of the 19th century and completely changed the science of biology. Even today, a hundred years later, scientists and scholars are still arguing about Darwin's theories.

In Darwin's time most people believed that the earth and everything living on the earth had been created just a few thousand years before. And they believed everything had remained in its original form; nothing had changed since the day of creation. This was known as the Theory of Special Creation.

But there were some scientists who disagreed. Charles Lyell the famous geologist was one. A well-known French biologist named Lamarck was another.



These men argued that the earth and its inhabitants were millions of years old. They said that in the beginning, only a few simple forms of life existed. All plants and animals now living arose from those first simple forms. They have been changing and developing down through the centuries. This slow process of change and development is called *evolution*.

Charles Darwin was attracted by the Theory of Evolution. But, as a scientist, he could not accept a theory without facts to back it up. He spent the next 23 years gathering those necessary facts. He studied thousands of plants and animals he had collected on his long sea voyage. Had such an endless variety of shapes and forms all been on earth since the day of creation? Why were there so many different ones? Why was this one found only in cold climates, and that one only in warm places?

And then there were the fossils he had dug up — skeletons of strange plants and fish and insects that had

lived and died centuries ago. Why didn't similar creatures exist today? These and many other questions puzzled Darwin. He could not completely accept the Theory of Evolution until he found the answers. He studied other men's experiments, and gathered all the available information about plants and animals — where they live, how they reproduce, how they adapt themselves to different climates and different living conditions. He did many experiments of his own, breeding pigeons, lizards and bees. He found that special breeding could change the characteristics of animals. He believed that a similar change of characteristics was often caused by "Nature."

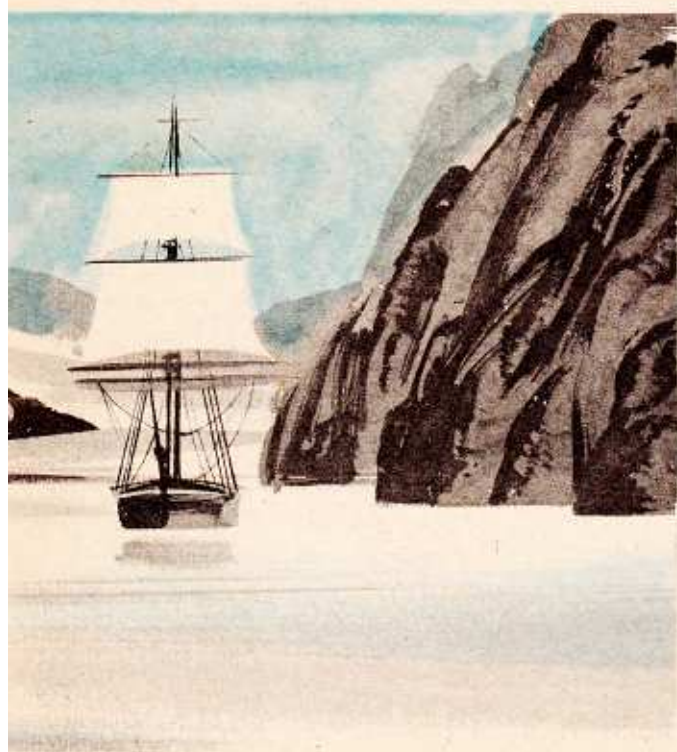
By 1859 Darwin was convinced that he had enough facts to prove the Theory of Evolution. He put them all together in a book called *Origin of Species by Means of Natural Selection*. If only he had known what a storm that book was going to stir!

To put it briefly, Darwin's book said there is no such thing as special creation. Plants and animals are descendants of different forms of life that once existed but are no longer on earth. Down through millions of years, a countless variety of new creatures has slowly evolved or come into existence including birds, insects, fish, animals and people.

So far, Darwin had not said anything very new. Hundreds of scholars had already proposed similar theories. But he was the first to offer facts to back up



FOSSIL IM-
PRINT IN
ROCK



The *Beagle* near Tierra del Fuego, the tip of South America. Darwin's studies of the primitive stage of the native's civilization was of the utmost interest.

his theory. For those who believed in the religious Theory of Special Creation, Darwin's book came as a shock.

Then came the idea that caused an even greater shock; the theory that Darwin called "natural selection" or "survival of the fittest." He argued that living things reproduce far beyond nature's ability to take care of them.

Suppose all the descendants of two elephants lived and reproduced. In just 750 years there would be nineteen million elephants! One bacterium can produce a million bacteria in just a day. Those million could produce several billion more the second day. If they all lived, we would soon be smothered by bacteria.

Darwin also noted that there is not enough food or water to keep alive everything that is born. Nature limits the number of living things by selecting the best specimens and destroying the others by disease, famine, storms, accidents and natural enemies. Only the

Darwin discovered that in some animals nature has developed a resemblance to animals which their enemies fear and avoid. The Caligo butterfly startles its enemies with spots under its wings resembling the eyes of an owl.

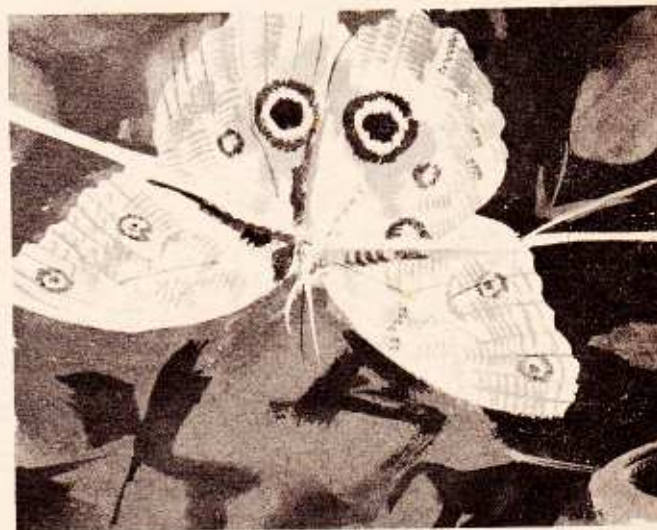


stronger, more adaptable ones survive — thus the phrase, "survival of the fittest."

The ones who survive, said Darwin, do so because they have certain superior

qualities. Perhaps they have better eyesight, stronger legs or sharper teeth. These traits are passed on to their offspring. And so begins a slow, gradual change in the species.

For example, after millions of years, horses' toes became hoofs. Some fish learned to breathe out of water and became lizards. Moles who lived underground for centuries finally lost the use of their eyes because they didn't need them in the dark. Man's legs gradually grew longer and his arms shorter.



Not since Galileo proved that the earth moved around the sun had there been such an uproar! Some people thought Darwin was a great genius. They called him "the Isaac Newton of biology." Others called him a sinful man who was against the teachings of the Bible.

Darwin was wise enough to keep out of the arguments and debates. He simply stayed at home working on another book. This one, called *The Descent of Man*, startled the world again, exactly twelve years later.

This time, Darwin stated that man and the monkeys share a common an-



Darwin's theories were based on extensive field work. While still with the *Beagle*, he spent five weeks exploring the Galápagos Islands off the coast of South America. He observed how reptile species, for instance the iguanas, of these islands resembled one another. Also, all of them showed strong resemblances to continental South American forms, but they varied distinctly from island to island. Wouldn't it be a waste if, as the Theory of Special Creation stated, a special community of animals should have been created for each island? Wouldn't it be much more logical and understandable, he argued, if the animals he observed were descendants of continental families and had only developed in different directions after having been isolated under different conditions on the islands?

cestor. Darwin did *not* say man is descended from the apes, as some people claim he did. He said that man and the anthropoid apes (apes that look like man) are distantly related, and that they are both descended from some unknown ancestor who lived millions of years ago.

Again loud protests and arguments were heard, both in Europe and America. His books were banned in many places. The debate raged on for years. As late as 1925, people in America were severely criticized and even arrested for teaching "Darwinism."

Although evolution is no longer de-

bated by scientists, there is still disagreement about Darwin's explanations of it. His theory of "natural selection" is not accepted by everyone. Modern biologists are constantly making changes and corrections, and several new theories have been presented.

But in spite of the disagreements about his work, Charles Darwin is recognized as a great scientist. Although there are still many questions about evolution that remain unanswered, Darwin made a tremendous contribution to science by taking biology out of the field of superstition, and putting it on a firm scientific basis.



How did the son of a soldier in Napoleon's army become one of France's most celebrated scientists?

Louis Pasteur

(1822-1895)

One day in 1885, a worried mother carried her nine year old son into the laboratory of the famous French chemist, Louis Pasteur. Two days before, the boy had been bitten by a dog with a disease called rabies. In the saliva of a rabid dog there are tiny organisms called rabies viruses. These viruses infect the victim of a dog bite with a deadly disease called hydrophobia. Unless something could be done, little Joseph Meister would die a slow, painful death from hydrophobia.

Louis Pasteur examined the suffering boy. Perhaps there *was* a way to save

him! For many years Pasteur had been trying to find out how to prevent hydrophobia. He had a special hatred of it. When he was a small boy, eight people in his village had died after being bitten by a rabid wolf. Pasteur was still haunted by their terrible screams of agony.

He tried thousands of different experiments, many of them very dangerous because he was working with fierce dogs infected with poisonous viruses. But finally, Pasteur found the answer to the problem. He weakened some poisonous rabies viruses. Then he made a fluid called a vaccine with the viruses, and injected the vaccine into a healthy dog.

Against all the doubts and mockery of his fellow scientists, Pasteur proved his findings by vaccinating and saving sheep during an anthrax epidemic.

After fourteen injections of the vaccine, the dog became immune to the disease. Even if he were then bitten by a rabid dog, the healthy dog would not get sick!

This was a remarkable discovery. But Pasteur had never tried it on a human being. Did he dare to vaccinate young Joseph Meister with the rabies vaccine? It might kill him. Still, without it, the boy would surely die. Quickly the great scientist made his decision and began the treatment. For ten days he injected increasingly stronger doses of rabies vaccine into the boy's body. And, wonder of wonders, it worked! Joseph did not get hydrophobia. Instead, he began to get well! For the first time in history a human being had been vaccinated against hydrophobia. Louis Pasteur had given mankind a most wonderful gift.

This was not the first of Pasteur's great scientific discoveries. For over 30 years he had been producing one miracle after another. No wonder he had become the most famous scientist in France.

Louis Pasteur was born in 1822, the son of a professional soldier in Napoleon's army. Strange to say, Louis Pasteur was not an outstanding student in school. But he did have two qualities that are necessary for success in science — curiosity and patience. As a teenager he wrote, "The most important words in the dictionary are Will, Work and Success."

After graduating from college, Louis went to work in a chemistry laboratory, studying chemical crystals. He made some important discoveries and was

gaining an excellent reputation as a chemist. In 1849 the French Ministry of Education assigned Pasteur to teach elementary physics at a secondary school in Dijon, and one year later, he was appointed acting Professor of Chemistry at Strasbourg University. As it happened, the head of the University had a pretty, dark-haired daughter named Marie. A week after they met, Louis asked her to marry him. She turned him down. As we said, patience is very important for a scientist, and it is equally important for a suitor. Louis persisted until a year later when Marie consented to become his bride.

The young chemistry professor soon found his interest turning from chemistry to biology, which is the science of all living things. Since the university was in the centre of the vineyards of France, a group of winemakers came to see Pasteur. They asked him if he could find out why some of their wine turned sour each year.

Peering through his microscope for hours and hours, Pasteur discovered that tiny organisms called bacteria were causing all the trouble. Then he found that bacteria in wine could be destroyed by heating the wine to a temperature of 140 degrees for 20-30 minutes. This is below boiling and does not affect the taste of the wine. Later, he did the same thing to milk to make it sweet and pure. We use the same process today and call it "pasteurized" milk.

One day it occurred to Pasteur that if these tiny organisms were found in food and liquids, they might also be living in the blood of animals and people, and causing disease. At that time in France, a terrible disease called



chicken cholera was killing millions of chickens. The chicken breeders begged Pasteur to help them. He began to look for the bacteria that might be causing the disease. Sure enough, he found them, swimming around in the blood of the sick chickens.

After weakening the bacteria, he injected them into healthy chickens. From then on, it was impossible for the vaccinated chickens to contract cholera. Pasteur did not invent the process of vaccination. About thirty years before he was born, an English scientist named Edward Jenner was the first one to successfully vaccinate a boy against smallpox. But Pasteur was the first one to find the bacteria that caused chicken cholera.

Next, Pasteur tried vaccinating cattle and sheep against a disease called cattle anthrax. He could not cure them once they had contracted the disease, but he *could* keep them from *getting* it. He inoculated sheep with weakened anthrax bacteria. What this actually did was give the sheep a light case of anthrax that was so mild they never even felt sick. After that, they could not con-

tract a fatal case of the disease. Pasteur and his assistants travelled through France for months, inoculating thousands of sheep. In this way, the French cattle and sheep industries were saved.

After his great triumph in vaccinating animals against disease, Pasteur was anxious to find vaccines that would prevent human diseases. This led him to experiment with rabid dogs, in search of a vaccine against hydrophobia. As we have seen, he finally succeeded, and saved the life of little Joseph Meister.

Louis Pasteur received every honour and every medal the grateful French people could give him. They even built the Pasteur Institute in his honour, in Paris. But fame and fortune did not change him. He kept right on searching for ways to prevent suffering by preventing diseases. He continued his experiments until he was confined to his bed by weakness and old age.

In 1895, when he was almost 73 years old, Louis Pasteur died in his sleep. The great scientist had certainly succeeded in his wish "to contribute in some way to the progress and good of humanity."

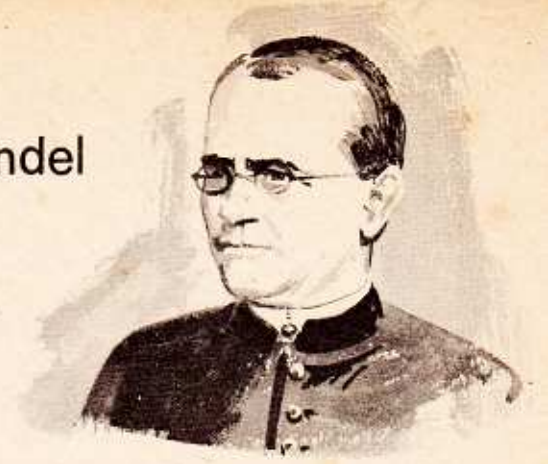


Little Joseph Meister, bitten by a rabid dog, is brought to Louis Pasteur.

How did he lay
the foundation for the
study of heredity?

Gregor Johann Mendel

(1822-1884)



Has anyone ever said to you "You have your mother's nose" or "You've inherited your father's eyes?" What they really mean is your nose looks like your mother's nose, and your eyes look like your father's eyes. Parents and grandparents often pass down certain physical traits to their children. A man with curly hair may have a curly-haired daughter. If both your parents have brown eyes, you probably have brown eyes, too. You inherit certain features: colour of eyes, length of nose, shape of ears, for example. This "passing down" of features is called *heredity*. And the study of heredity is a science called *genetics*.

It was a jolly, fat little monk named Gregor Johann Mendel who first studied heredity in a scientific way. He was the first to establish laws to explain heredity. These laws were the beginning of the science of genetics. Until he came along, nobody knew exactly how people inherited blue eyes or long noses or small feet. And strangely enough, it was a garden full of peas that first gave Friar Mendel his inspiration to find out about heredity!

Mendel's father was a poor peasant and gardener in a country called Moravia, which is now a part of Czechoslovakia. Little Johann loved to help tend the plants in his family's garden. Even as a boy he asked countless questions. "What gives the flowers their different colours and shapes?" "Why does this apple tree have red apples, while

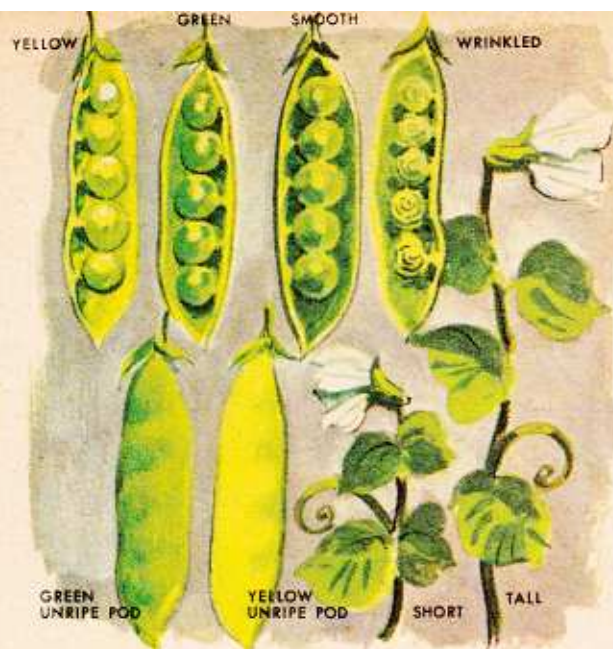
the apples on that tree are yellow?" His father was quite embarrassed because he didn't know the answers. At that time, nobody knew the answers.

The Mendel family was very poor, but after much scrimping and saving, they managed to put Johann through four years of college. When he was twenty-one, he entered a monastery and took the religious name of Gregor, in honor of Saint Gregory.

Brother Gregor had made a wise choice. He was very happy at the monastery. His fellow monks were friendly, intelligent men who enjoyed lively discussions about everything from religion to literature, art and science. There was a fine well-stocked garden, and since Gregor enjoyed gardening, he was put in charge of it. He also continued his religious studies, and in 1847 he was ordained a priest.

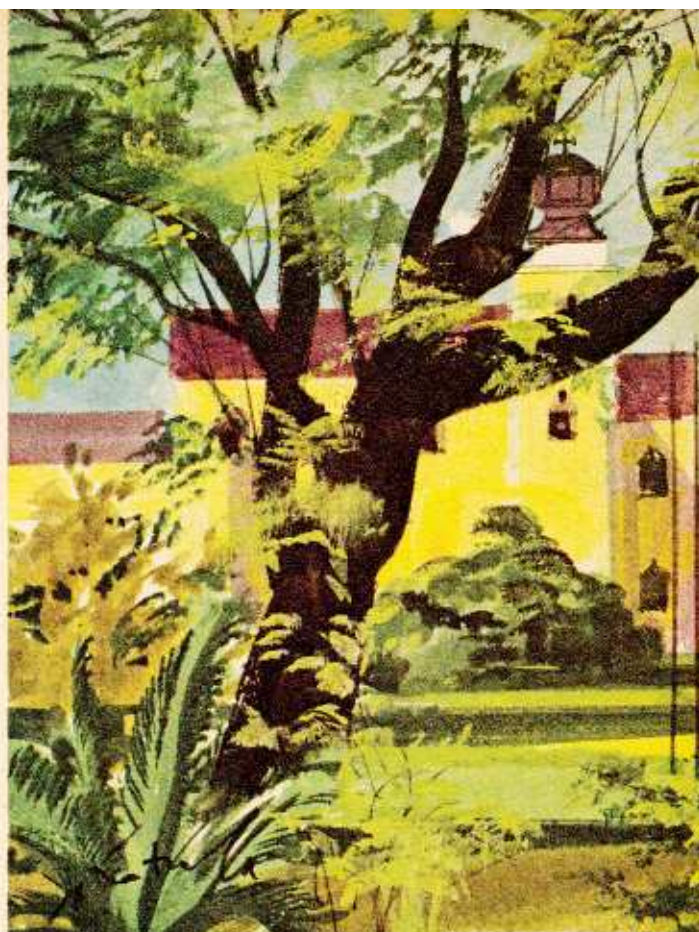
Because Brother Gregor was interested in science, the Church sent him to the University of Venice for two years, to study physics. When he returned he became a physics teacher at the local school in Altbrunn, the town where his monastery was located. His teaching did not interfere with his duties as a monk. He continued to live at the monastery and to tend his garden every day.

There, just as he used to do when he



In his study of pea plants, Mendel discovered that in crossing plants with pairs of contrasting traits, one trait is dominant and the other recessive.

Since he enjoyed gardening, Brother Gregor was put in charge of the monastery garden.



was a boy tending his father's garden, he began to ask questions. Why were some peas smooth and others wrinkled? How could he be sure of raising only the smooth ones? Sometimes when he planted the seeds of a plant with red blossoms, a few of the new plants grew up with pink blossoms. Why was this?

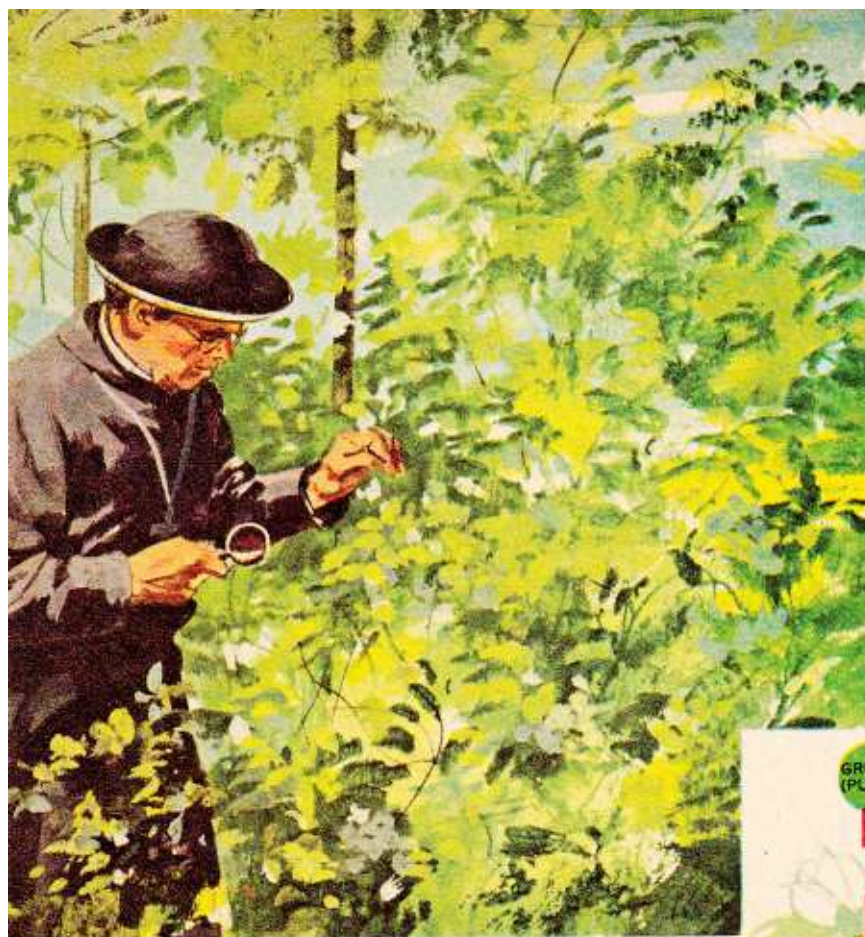
Finally his curiosity got the better of him and he decided to make some experiments that were really scientific. Instead of just guessing, he would make careful observations and write down everything he learned. He chose to work with peas, since they were easy to grow. Because they had a short life, he could study many generations. During the eight years from 1856 to 1864 he planted and observed 10,000 different pea plants!

Here's an example of a problem Gregor Mendel tried to solve. Would

the offspring or "children" of a tall pea plant and a short pea plant be tall or short? In order to make the tall plant and the short one reproduce, he took a bit of the golden dust called pollen from a tall plant. Then he placed the pollen on the pistil or seed-container of a short plant. The resulting seeds were then planted. Everyone of the offspring were tall like the "father" plant. Mendel called tallness the *dominant* trait.

When these tall offspring reproduced, Mendel found that the second generation, or "grandchildren" were not all tall. For every three tall ones there was one short one. That short one had inherited its "grandmother's" shortness. Mendel called shortness the *recessive* trait.

In this same way, Gregor Mendel cross-bred peas with yellow seeds and peas with green seeds. He found that



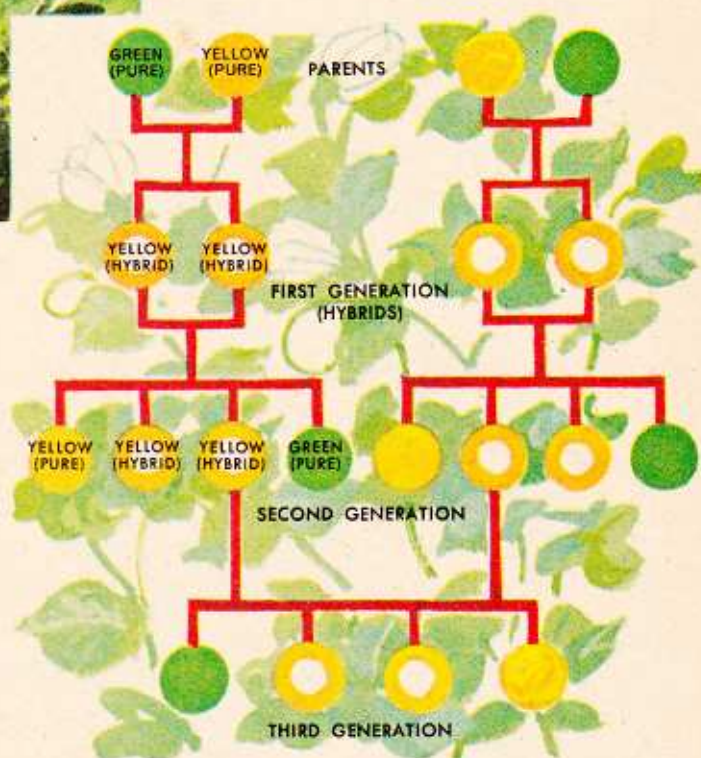
Brother Gregor discovered what became known as Mendel's Laws of Heredity. From his experiments, he proved that:

1. Single traits or characters, such as colour of seeds or size of the plant (in peas), are transmitted from one generation to the next and not lost.
2. If two organisms with opposite traits are crossed, the hybrid offspring acquire the traits of both parents. One of the traits is dominant, however, while the other is recessive.
3. When the offspring, the hybrids, are crossed again, the traits separate out again in the ratio 3:1. This means the 1 shows the pure recessive trait, and the 3 others have the outward appearance of the dominant trait; however only one is really pure dominant; the other two are mixed dominants, and actually hybrids again.

the "children" or first generation offspring all had yellow seeds. But the second generation, or "grandchildren" were three yellow to one green. Yellow was the *dominant* trait, green was the *recessive* trait.

He repeated these same experiments hundreds of times. Each time they came out the same. After eight years of careful, patient work, he felt confident enough to say that plant heredity works according to certain strict, unchanging laws. Of course he could not do the same experiments on people, so he was unable to apply the same rules to human heredity.

Naturally he was excited about his new theories, and he decided that the time had come to tell the world what he had discovered. In 1865 he wrote an essay and read it at a meeting of the town's scientific society. But nobody



seemed to know what he was talking about. They applauded politely and promptly forgot what he had told them. Perhaps he hadn't explained himself very clearly.

He went home and rewrote the paper. A few weeks later he read it at another meeting, but again, nobody was very interested. Perhaps they just didn't think an experiment with pea plants was

important. The speech was printed in a small scientific magazine, but it was soon gathering dust on the library shelves, unread and unappreciated.

Of course, Gregor Mendel was discouraged. But he was a cheerful man and he didn't let it get him down. "My time will come," he told his fellow monks.

In 1869, he was elected Abbot of the monastery, and from then on he was so busy running the establishment that he had no more time for research. When Gregor Mendel died in 1884, he was remembered as a kindly, hard-working little monk who had wasted a lot of time fooling around with peas in his garden. His lifework, *Mendel's Laws of Heredity*, was unknown.

Not until sixteen years after his death did the world discover what a great scientist Mendel had been. In 1900, by some strange chance, three European scientists discovered the long-forgotten article that Mendel had published 30

years before. They immediately realized how important it was, and spread the news to scientists everywhere.

It was soon found that Mendel's laws were true not only for plants but for animals and people, too. Later experiments showed that there are a few exceptions to his rules. We no longer call them Mendel's Laws, but Mendel's Theories.

His theories have been of great help to farmers by showing them how to produce better varieties of wheat, corn and other crops. Cattle breeders have been able to produce stronger, healthier cows and sheep, by using the same principles. And right now, medical scientists are applying the Mendelian theories to find out whether people inherit a tendency to certain diseases, and if so, how this inheritance can be controlled.

We are all benefitting in some way from the knowledge passed down to us by the beloved little monk, Gregor Johann Mendel.



Marie Curie

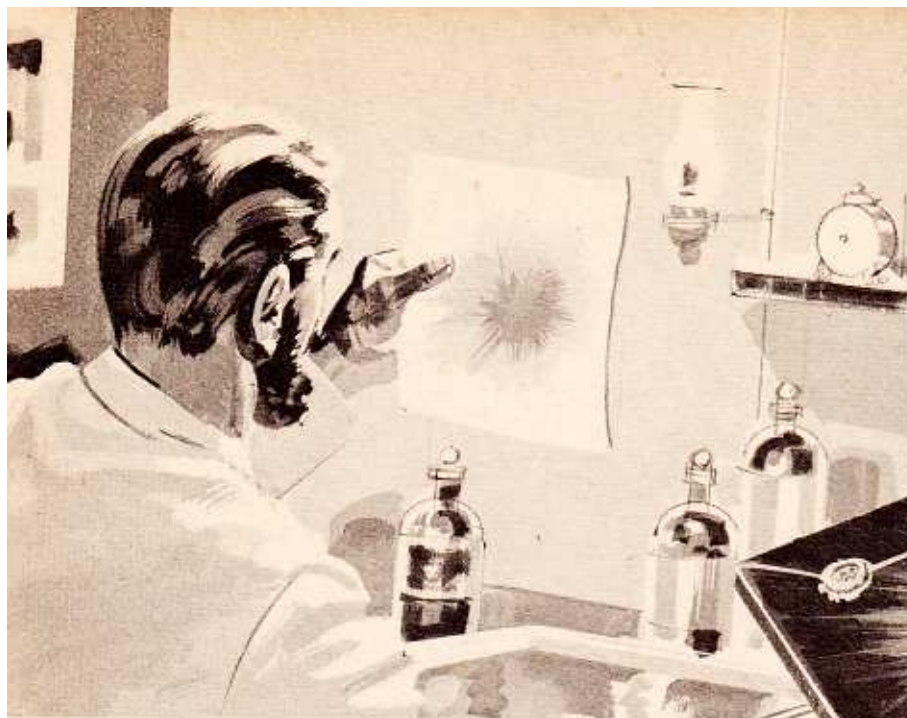
(1867-1934)

How did her tireless work earn her two Nobel Prizes and the first professorship for a woman?

When we think of a scientific laboratory, we usually imagine a man in a white coat working in a big, bright room

filled with sparkling test tubes, microscopes and other expensive equipment. But this is not always the case. One of history's most important discoveries was made by a small, frail woman working in an old woodshed with a dirt floor, cracked windows and a leaky roof.

This is the story of Marie Curie and her long, hard struggle that ended in the discovery of a wonderful new sub-



By accident, Becquerel had discovered that uranium, and to a greater extent pitchblende, blackened a photographic plate even through a light-proof cover. Becquerel and Pierre and Marie Curie, with whom he started to work, shared the Nobel Prize in Physics in 1903 for their discoveries.



URANIUM ORE ON UNEXPOSED PHOTOGRAPHIC PLATE.

stance called radium. Radium is a rare metallic element that is used today to treat the dread disease, cancer. It is very valuable. To buy one tiny gramme of it (there are about 28 grammes in an ounce) you would need £10,000.

In 1895 when Marie Curie, who was born Marja Sklodowska on November 7, 1867, in Warsaw, Poland, first started working in her crude little woodshed "laboratory," neither she nor anyone else had ever heard of radium. She was a young chemist who had just married a brilliant but poor French scientist named Pierre Curie. They lived in a small apartment in Paris. Marie worked with Pierre in his laboratory, helping him conduct experiments with electricity.

A fellow-scientist named Henri Becquerel had recently made an exciting discovery about a metal called uranium. He found that it gave off mysterious invisible rays or energy. He accidentally left a piece of uranium on an unexposed photographic plate that was covered with black paper. The next morning the

plate was fogged as if light had reached it. Apparently the rays from uranium had penetrated through the black paper!

Becquerel then tried the same thing with a piece of pitchblende, a hard black substance in which uranium is found. Pitchblende affected the photographic plate even more than the uranium. There must be another element besides uranium in pitchblende. He discussed his theories with his friends, the Curies. They became fascinated by the mystery. What were the strange rays that could penetrate objects that ordinary light rays could not? Did any other elements have this power of radiation?

One by one, Marie Curie tested all the elements that were then known to science. She found that only uranium and thorium had this radiation activity, which she named "radioactivity." But Becquerel thought there was an unknown element in pitchblende that was

even more radioactive than uranium. Marie Curie must try to find it.

Pierre was now teaching at the School of Physics, but he began to spend all his spare time helping his wife in her search. Before they could go ahead, two things were needed: large amounts of pitchblende to study and analyze, and a laboratory to work in. The head of the School of Physics said they could use a dilapidated storeroom next to the school courtyard. It was damp and draughty, but it was available free of charge, so they accepted it.

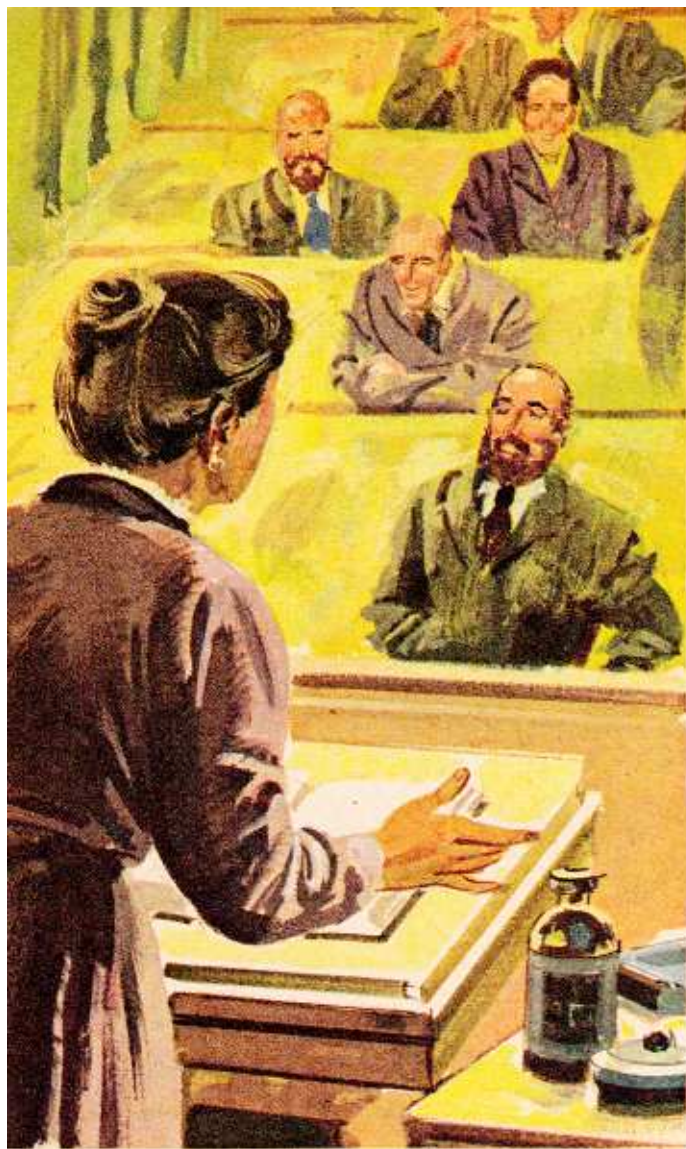
Next, where could they get pitchblende? It was far too expensive for them to buy. Luckily they heard that the Austrian government had tons of pitchblende that was considered worthless because all the uranium had been removed. Since they were seeking some other element besides uranium, this pitchblende "rubbish" was just what they wanted. They were able to buy it simply by paying the shipping charges.

Wagon loads of black stuff that looked like ordinary earth, began arriving at their shack or "laboratory." First it had to be purified. Marie and Pierre would shovel the earth into huge pots, mix it with chemicals, then heat it on an old cast-iron stove. Then they stirred it, for hours and hours. Smelly dark clouds of smoke poured out and nearly smothered them. Their eyes watered and it was very hard to breathe. When the pitchblende had boiled long enough, they carefully poured it through strainers and filters. A few drops of precious stuff was all that remained. This was carefully sealed into glass test tubes.

The first winter Marie caught pneumonia and was very ill for three months. But as soon as she was strong enough, she went back to the smoky workroom and the boiling cauldrons. The next year their first daughter, Irene, was born, but Marie was back at the lab again in a week. Fortunately, Grand-

Pierre Curie (1859-1906) and his wife, working together in their makeshift laboratory, try to isolate the "ray-producing" material from the pitchblende. For succeeding to isolate the element radium, Marie Curie received a second Nobel Prize in 1911, this time in chemistry.





Marie Curie, the first woman ever to teach at the famous university of Paris, the Sorbonne, started her lecture exactly at the point where Pierre Curie had left off.

named "radium" from the Latin word "radiare" which means "to shed rays." It is over a million times as radioactive as uranium!

With Becquerel, the Curies received the Nobel prize for their accomplishment and they used the money of the prize to pay off the debts of the many years of purifying pitchblende.

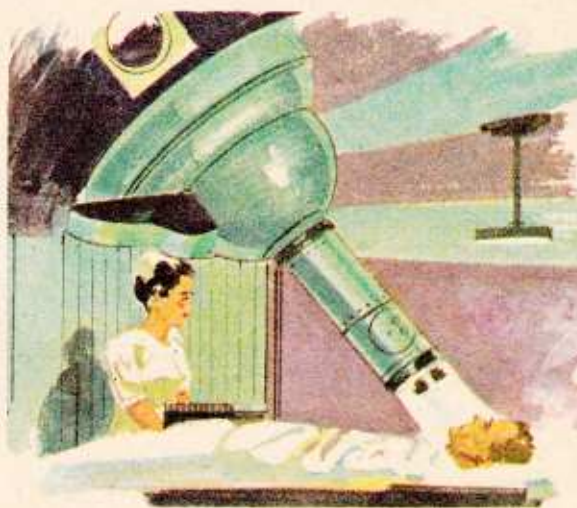
Although they now knew radium existed, it took them four more years to actually collect a few grains of radium salts. By then the Curies had shovelled and melted and boiled and filtered EIGHT TONS of dirty pitchblende!

These radium salts were tiny white crystals that glowed in the dark. The

father Curie came to live with them at that time, and he was happy to baby sit while Marie and Pierre were busy with their work.

In 1898 Pierre gave up his teaching position, and for the next eight years he and Marie worked side by side in their dark, ugly shed. They had chosen a very difficult task, but they were determined to stick to it until they succeeded. In July of that year they announced that there was not one, but *two* new radioactive elements in pitchblende!

Marie Curie called the first one "polonium" in honour of Poland, the land where she was born. The second, and by far the most important one was



Without the Curies, today's radium treatment of many diseases would, most likely, not be possible.

Curies discovered that radium was dangerous to work with. One little crystal, even inside a closed metal container, could burn the skin and cause a large sore. After they had worked with ra-

dium for a short time, they both had sore, scarred, painful fingers.

The fact that radium has the power to kill human tissue, turned out to be a most important discovery. Doctors and medical scientists soon found that radium could be used to destroy tumours and growths that occurred in the dread disease, cancer. Radium could be a great saver of life!

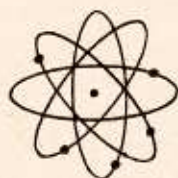
Now the Curies were more anxious than ever to produce radium in its pure state. Unfortunately, Pierre Curie did not live to share in his wife's triumph. He died in 1906 after being accidentally run over. His grief-stricken widow was left with two small daughters. After recovering from the terrible shock of his death, Marie Curie went back to her drudgery. The French, breaking all their traditions, offered to let her succeed her late husband as professor of physics, thus making her the first

woman in France to reach such a position. Two more years went by. Then at last she managed to produce a single gramme of pure radium. She had finally reached her goal! For this work she received a second Nobel prize.

Marie Curie could have sold that tiny gramme of radium for £50,000, but she would not take any money for it. "Radium is an instrument of mercy," she said, "and it belongs to the world."

Today, thanks to the determination, skill and courage of this dedicated woman, many cases of cancer are being successfully treated and controlled. Medical researchers are hopeful that one day soon they may learn how to rid the world of this terrible disease forever.

And, of course, the discovery of radioactivity by Becquerel and the Curies led to the later development of atomic energy. The stage was set for the new scientific age in which we are living.



Albert Einstein

(1879-1955)

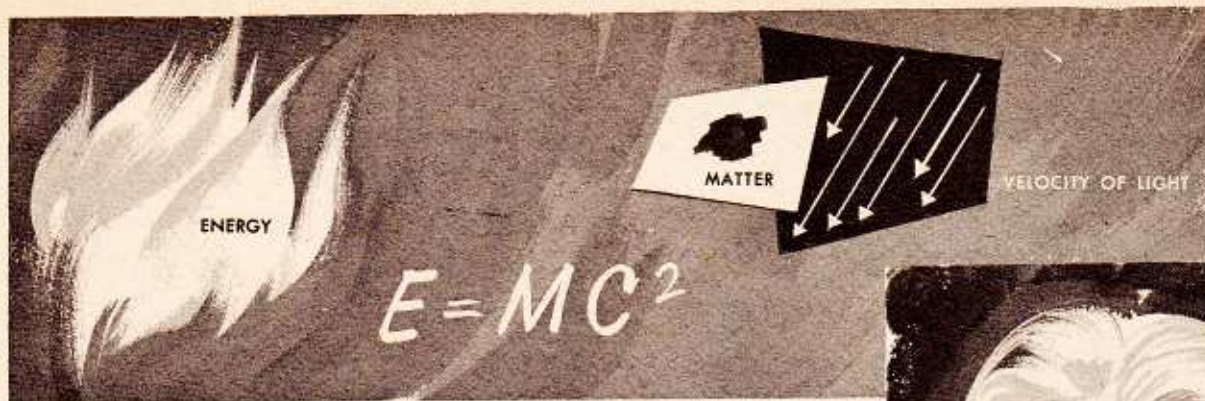
How did his formula of 1905 lead to the atom bomb of 1945?

Most of the scientists you have read about in this book worked with microscopes, telescopes or some kind of laboratory equipment. They performed experiments in order to solve the problems they were working on, or find the answers they were looking for.

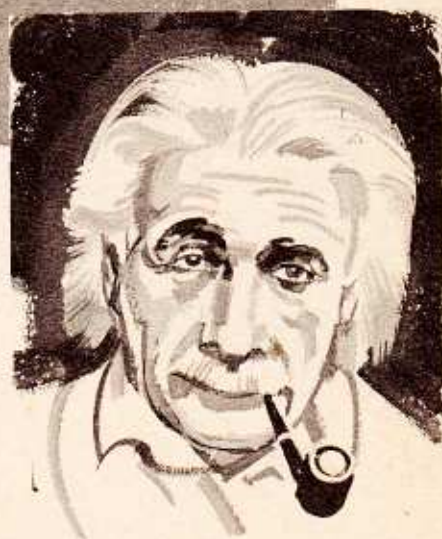
Albert Einstein was a different kind of scientist. He was a *theoretical* physicist who made his discoveries, not in a laboratory, but in his mind. He did not perform experiments to prove his

theories. He devoted his entire genius to conceiving and developing ideas, and then turning them into written mathematical formulas.

Some of Einstein's theories were so far ahead of their time that they could not be tested until years later when better scientific instruments and equipment had been invented. For instance, one theory pointed out the existence of a certain star that nobody had ever seen. Another predicted that an atom, then



The development of the atomic bomb during World War II was based on a conclusion Einstein had reached in 1905: While previous scientific theory held that matter could neither be created nor destroyed, Einstein concluded that mass (matter) could be changed into energy, and energy into matter. He expressed this with the simple-looking formula $E = mc^2$, E standing for Energy, m for mass, and c for the velocity of light.



considered the smallest particle in the universe, was actually composed of even smaller particles. Eventually, both theories were proved to be true!

Albert Einstein gave the world many new mathematical formulas that helped explain the laws of the universe. No one in history has done so much as Einstein to help us understand such mysterious things as light, energy, motion, gravity, space and time.

He was born in the small town of Ulm, Germany, and grew up in the suburbs of Munich, where his father owned a small electrical factory. As a youngster, he showed very few signs that he would one day be called a scientific genius. He was very slow in learning to talk. He did so poorly at school that his teachers called him "dull and backward." That was one time the teachers were wrong.

Actually, Albert Einstein was extremely intelligent. By the age of 12 he had taught himself geometry and calculus — two difficult subjects usually taught in high school and college!

When he was 16 his father urged him to go to work in the family's electrical business. But Albert wanted to continue his studies, especially mathematics and physics. He planned to become a physics teacher. He went to Zurich, Switzerland and enrolled in the Polytechnic Academy. There he made good grades and earned a teaching certificate. He also met a student named Mileva Marec, who later became his wife.

After graduation, young Einstein was unable to find a position as a teacher. He found a few tutoring jobs, but they paid very little. For months he had barely enough to eat. Finally, in 1902, he became a clerk at the Swiss Patent Office. This was a poorly paid job, too, but it was just right for Albert Einstein. The work was easy and it left him a great deal of time for thinking and studying.

For the next three years he spent every free minute working on formulas



Einstein, in the park in Princeton, was often seen helping children with their arithmetic.

that would give the world a new mathematical explanation of time and space. When he wasn't examining patents at the patent office, he was bent over his desk, filling notebook after notebook with equations and figures. In 1905, when he was only 26 years old, he published the theory that made him famous. It was called "Special Theory of Relativity." Some scientists have called it "the most important document in history."

Einstein's Theory of Relativity was not received with enthusiasm by his fellow scientists. It showed up many errors in their own work, and forced them to re-examine their calculations. But by 1912 the hostility had disappeared and the scientific world began to acclaim him as a great man. His theory was very complex, but it answered many questions that had puzzled mathematicians and physicists for years. And it served as a springboard for exciting new research and discoveries.

The obscure clerk soon became a world-famous figure. He was invited to lecture at leading European universities. "A new Copernicus has been born," said one professor. Many excellent teaching positions were offered to him. In 1914 he became Physics Professor at the University of Berlin, where he stayed for nineteen years. In 1921 he won the Nobel Prize for Physics.

Suddenly, in 1933, his whole life changed. Adolph Hitler had risen to power as the dictator of Germany. Hitler and his followers persecuted the Jews and threw millions of them into prison. Hitler declared he would one day conquer the whole world. He eventually started World War II.

Albert Einstein was quick to speak out against Hitler and the Nazi cruelties. Hitler took revenge by destroying his house, seizing all his property and offering a large reward for his arrest. Albert Einstein, the world's most brilliant scientist, honoured and admired by millions, was a refugee without a home.

But then he received an invitation from America. The Institute for Advanced Study at Princeton, New Jersey,



would be proud to have him as a life member. So, in 1933 he came to Princeton. For the next 22 years, Dr. Einstein lived and worked there. He became a familiar figure on the college campus — a small man with bushy white hair who walked from his home to his office every day, no matter what the weather.

He was fond of children, and often he would help a little neighbour girl do her arithmetic homework. The famous professor lived a quiet life. In the evenings he enjoyed chatting with friends or playing his violin. He deeply loved the U.S.A., where he had found peace and freedom, and in 1940 he became an American citizen.

In 1945 America ended World War II by exploding the atom bomb, which was based on some of Einstein's earliest (1905) conclusions: matter (mass) could be changed into energy and energy could be changed into matter. This contradicted all previous scientific theory that "matter" could be neither

created nor destroyed. Einstein himself had drawn President Franklin D. Roosevelt's attention with a letter in 1939 to the experiments of Fermi and Szilard, which were based on his formulas. He had not meant his work to lead to destruction and death. He greatly regretted that science had used atomic energy as a weapon, instead of using it to benefit mankind. He urged all nations to unite in a peaceful world government to prevent further atomic wars and terrible suffering.

Albert Einstein never stopped searching for answers to the mysteries of the universe. Among his later theories were valuable mathematical explanations of the laws of gravity and electromagnetism. He died in 1955 at the age of 76. He will long be remembered as a gentle, modest man whose scientific genius opened up a whole new world of knowledge. His name will go down in history as one of the greatest thinkers who ever lived.



Alexander Fleming

(1881-1955)

Why did he consider his discovery a stroke of good fortune?

Can a great scientific discovery be the result of "a stroke of good fortune"? That's how Alexander Fleming described his discovery of the wonder drug, penicillin.

But Dr. Fleming was just being modest. It takes more than luck to find and develop one of the greatest life-saving chemicals of all time. It takes curiosity, imagination and years of scientific training.



Laboratory workers preparing culture beds for today's research in antibiotics — the wonderdrugs — of which penicillin was the first to be discovered.

Alexander Fleming had all three. He was born in Scotland, and after graduating from High School he went to England to attend medical school. He received his doctor's degree from London University in 1906, and decided to specialize in medical research. He was especially interested in the study of bacteria. Bacteria are tiny one-celled plants so small they can be seen only through a microscope. A single drop of water may contain thousands of them.

Although some bacteria are beneficial to man, most of them are dangerous. Such diseases as diphtheria, typhoid fever, pneumonia and tuberculosis are caused by bacteria. These little microbes are found everywhere — in the air we breathe, in water, on the food we eat, on our skin and in our blood. Right now you are probably carrying thousands of bacteria around in your body. But don't worry; the body has many ways of defending itself. Our most effective bacteria fighters are the little white cells in the blood called white corpuscles.

Alexander Fleming spent many years studying disease-producing bacteria. He worked in the laboratory at St. Mary's Hospital in London, where there were patients with all kinds of diseases. From these patients he could obtain almost any type of bacteria he wanted to study.

In 1914, when the first World War broke out, he was sent to France as a Captain in the Royal Army Medical Corps. As he treated wounded soldiers, he saw that harsh antiseptics sometimes did more harm than good. True, they did destroy some disease-producing bacteria. But they also killed the white

blood corpuscles that are the body's best defence against infection. Fleming promised himself that when he got back to his laboratory, he would try to find some kind of bacteria fighter that would not be so harmful to human tissue.

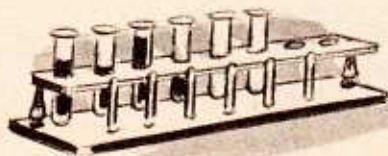
In 1922 he made the remarkable discovery that human tears contain a chemical that can dissolve certain bacteria. He called this chemical lysozyme (*lie-so-zime*). He also found lysozyme in perspiration, saliva and in the gastric juices of the stomach. The lysozyme and the white corpuscles in your body are constantly at work protecting you from harmful bacteria.

To study bacteria under the microscope, scientists grow them in small flat dishes of gelatin. These gelatin dishes are kept covered so that no other kinds of bacteria can get in. As the original bacteria multiply, they form a tiny speck known as a colony, which is big enough to be seen without a microscope.

In 1928 Fleming was studying certain bacteria that cause boils and other infections. He had over a hundred gelatin dishes in his laboratory, and every day he would lift the lids to examine the bacteria growing in the gelatin.

Then one day the "lucky accident" happened. He noticed that a speck of blue-green mould was growing in one of the dishes. It must have drifted in unnoticed, while he had the lid off at some previous time. Now, this often happens in bacteriology laboratories, and the ordinary scientist usually says "Well, there's another one ruined," and throws the whole thing away.

But Alexander Fleming was not an ordinary scientist. His curiosity told him



he'd better investigate. He put the contaminated dish under the microscope and took a closer look at the mould.

It was a common mould. It belonged to the *Penicillium* group. *Penicillium* comes from the Latin word meaning "small brush" which is a good description of the shape of the tiny *Penicillium* growths. *Penicillium* is closely related to the mould found in Roquefort cheese or on mouldy bread.

But this particular bit of mould had done something very unusual. It had killed the deadly bacteria that surrounded it on the dish! Since bacteria-killing was his specialty, Dr. Fleming was very interested in this new mould. He named it penicillin and began to find out more about it.

He transplanted bits of the mould into clean, sterile gelatin dishes. Then he began putting different types of bacteria in with the penicillin. In some dishes the bacteria were not affected at all. But in others the mould completely destroyed them. He had found something remarkable! Next, he tried growing the mould in different fluids — and he found that these fluids could kill certain bacteria, too. Now he was really excited. He let the mould grow for a few days, and saw a golden fluid oozing out. He mixed this golden fluid with water, and it, too, killed certain types of bacteria. His next step was to find out if the penicillin could kill bacteria in animals without harming their delicate tissues or destroying their white blood corpuscles. Time after time he injected it into mice and rabbits infected with diphtheria, pneumonia and meningitis. And time after time these sick animals got well! This

meant that the white blood corpuscles and the penicillin could work together to destroy bacteria!

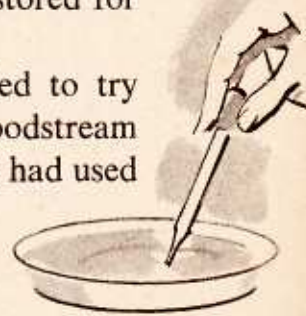
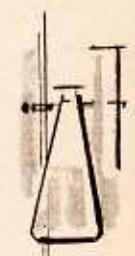
After he was satisfied that penicillin would not harm delicate tissues, he mixed it into a salve and rubbed it into sores of some of the patients in the hospital. He was disappointed to find that it wasn't any more effective than the ointments already used.

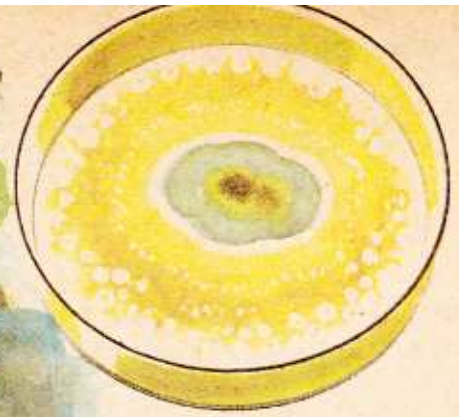
Fleming experimented with penicillin for several years. But finally he realized he could go no further with it. He had no more money for experimenting. He still had not found a way to produce enough of the golden fluid to do much good. And, penicillin lost its power if it was stored for any length of time.

Fleming needed the help of other scientists to develop his bacteria fighter. He needed chemists to find a way to produce larger quantities of penicillin. He needed doctors to test it on human beings. But strangely enough, nobody seemed to be interested. By 1933, the new group of remedies called "sulfa" drugs had been developed and many doctors were busy testing them.

It wasn't until 1939, that two British scientists, Professor H. W. Florey and Dr. E. B. Chain decided to do some research on Fleming's penicillin. They found that it was many times as effective as sulfa drugs, and that it worked miraculous cures on mice infected with deadly bacteria. When they dried the golden fluid to a brownish powder, it kept its power and could be stored for long periods of time.

In 1941 Dr. Florey decided to try injecting penicillin into the bloodstream of human beings. Dr. Fleming had used





Sir Alexander Fleming and a close-up of a dish containing bacterial solution which was inoculated with penicillin mould. The area in the centre is the penicillin mould; the area around the mould shows solution

free of bacteria growth; the area around the rim of the dish shows the solution with heavy bacteria growth.

it externally on a few patients, but had never tried using it internally to fight disease.

Dr. Florey's first patient was a policeman who was near death from a terrible infection. For five days he was given penicillin injections. At the end of that time his temperature was back to normal and he was feeling well enough to sit up and eat his dinner. But there was no more penicillin available, and not enough time to make any more. The policeman grew worse and finally died. This was an unfortunate tragedy, but from it the medical world learned that penicillin was a wonderful infection fighter. If only enough of it were available.

Penicillin was very difficult to produce. Great amounts of it were needed, because World War II had started and thousands of people were being wounded. England was using all her factories and manpower to produce ammunition and defence materials. But America had not yet entered the war. Perhaps American factories could be used. American scientists and industrial

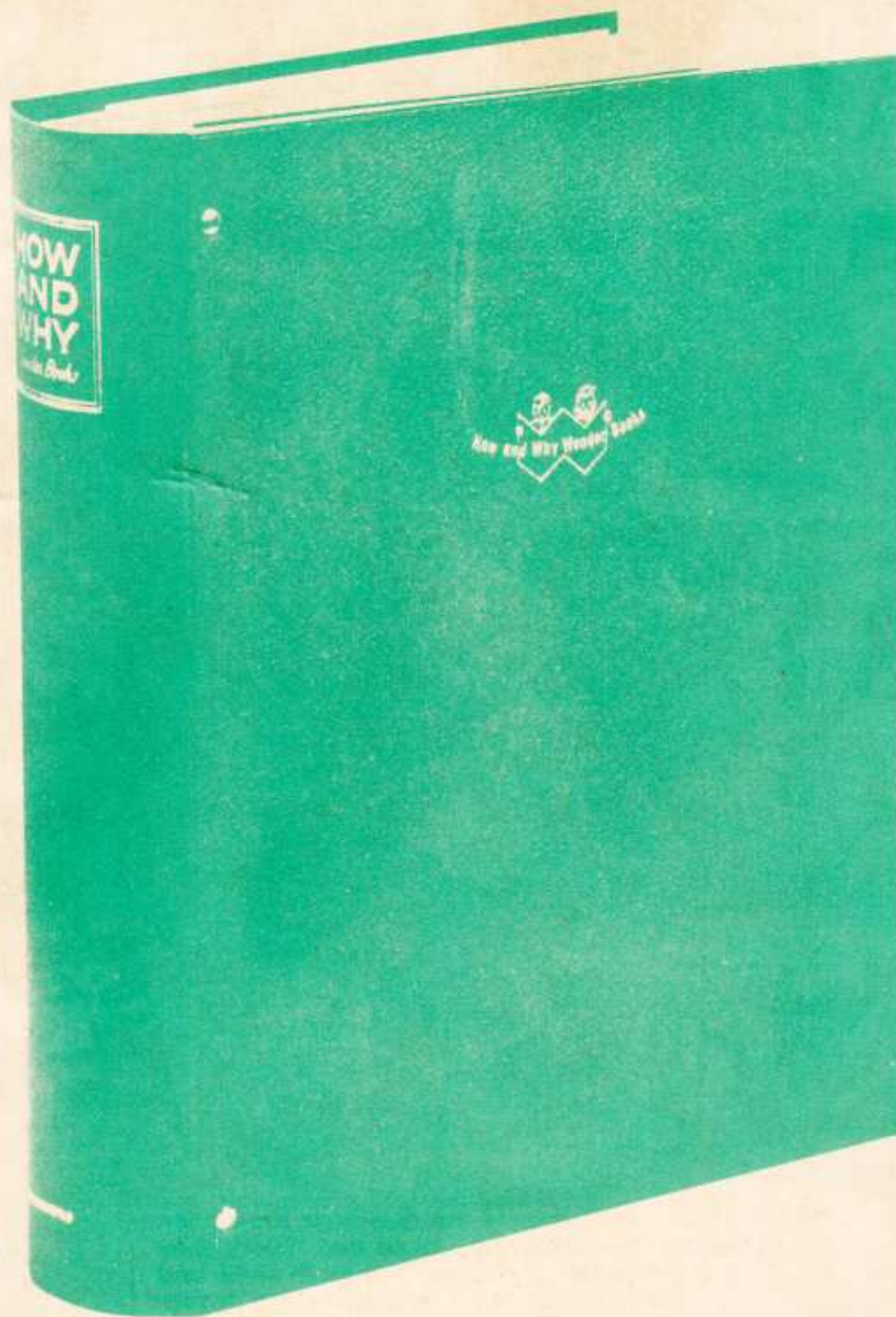
experts got together and worked out ways to make huge amounts of penicillin using assembly-line methods. Little by little, production of penicillin increased. By 1944, tons of it were produced and shipped overseas to the war areas. The lives of thousands of fighting men were saved by this precious golden substance.

In June of 1944 Alexander Fleming and Dr. Florey were knighted by the King of England for having discovered and developed penicillin. In 1945, these two men and Dr. Chain were jointly awarded the highest honour the scientific world can bestow. They were given the famous Nobel Prize, plus £10,000 to be divided among them.

Today the cost of penicillin has been sharply reduced. But the price is still very high. Many people in other countries cannot afford to buy it. Science and industry are hard at work trying to produce it even more cheaply. Perhaps one day everyone in the world can have this wonderful bacteria-fighter discovered by Sir Alexander Fleming, a man whose scientific mind made a miracle out of a "lucky accident."

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